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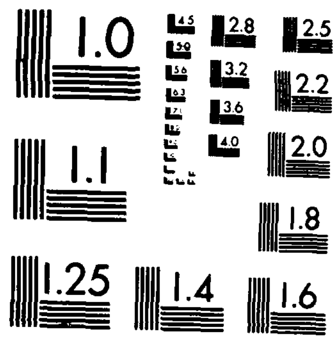

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MEASUREMENT OF AIR FORCE ENVIRONMENTAL

PROTECTION PROGRAM PERFORMANCE

THESIS

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AFIT/GEM/LSM/86S-7

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MEASUREMENT OF AIR FORCE ENVIRONMENTAL PROTECTION PROGRAM PERFORMANCE

THESIS

Presented to the Faculty of the School of System and Logistics

of the Air Force Institute of Technology

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Master of Science in Engineering Management

Steven W. Coyle, M.En.

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Abstract

The purpose of this research was to determine if an analysis method could be developed for the Civil Engineering Environmental Planning Function. The modeling technique chosen for this effort was Constrained Facet Analysis (CFA) which is capable of evaluating an organization based on a set of multiple inputs and outputs. The most time-consuming aspect of the research was determining appropriate input and output measures for environmental planning organizations, since the functions are service-oriented and have few variables which are suitable for typical quantitative analysis. Many of the variables selected were considered "result" oriented in that they measured the effectiveness of functions in meeting compliance requirements. The model evaluated the measures to identify efficiency ratings for environmental planning organizations and identified which variables caused the inefficiencies. The analysis was accomplished by collecting data from base environmental functions and processing the data using the computerized CFA model, Productivity Assessment Support System. The results showed that, with certain limitations, the measures and CFA could be used to model the performance of environmental organizations. Field study of CFA use for Air Force Civil Engineering was recommended.

MEASUREMENT OF AIR FORCE ENVIRONMENTAL PROTECTION PROGRAM PERFORMANCE

I. Introduction

General Issue

Starting in the late 1970's, the Executive Branch placed increased emphasis on improving the efficiencies of government agencies. In 1982, the Air Force responded by establishing a functional review program to evaluate organizational performance. The Air Force Engineering and Services Center (AFESC) assumed responsibility for the functional review of Engineering and Services organizations. The effort was named Project IMAGE (Innovative Management Achieves Greater Effectiveness) to reflect the need to improve not only efficiency but overall performance. AFESC initiated Project IMAGE by holding a series of workshops for functional managers and conducting or sponsoring organizational reviews.

In conjunction with AFESC's Project IMAGE, several Air Force Institute of Technology students studied the performance of Air Force Civil Engineering organizations. Byers and Waylett (11) specifically referred to the need for additional performance reviews of other Civil Engineering functional areas. The Air Force environmental protection program is one area which has not had a performance evaluation. In general, the environmental program has not been the subject of many management studies due, in part, to its relative newness. Because of the critical nature of environmental affairs, the Air Force can benefit by better understanding the environmental program and its responsible organizations.

Problem Statement

The Civil Engineering Environmental and Contract Planning Organization has primary responsibility for the environmental program at most bases. The AFESC functional review workshop for this organization was held 10-14 May 1986. The workshop participants developed a performance work statement and a quality assurance plan, and identified an exhaustive list of organizational tasks. However, the group did not identify input and output measures and a model which could use the measures to adequately evaluate organizational performance. The specific problem of this research is: How can performance of the environmental protection program best be evaluated, and how can performance evaluation methods best be used by Air Force operational units?

Objectives

The objectives of this research are as follows:

1. Determine appropriate input and output measures which define the operations of the environmental protection function.

2. Collect data on the measures from Air Force Civil Engineering functions.

3. Analyze the data using a measurement technique such as ratio analysis, linear regression, Data Envelopment Analysis, or Constrained Facet Analysis.

4. Evaluate the measures and analysis method.

5. Discuss the feasibility of the practical application of this technique.

Investigative Questions

In the pursuit of investigating the specified problem, several investigative questions need to be answered:

1. What characteristics best describe the environmental protection program?
   a. What are the environmental program structures and what are the functions which transform inputs to outputs?
   b. Are there similar programs/organizations in the Department of Defense or private sector which can help describe these characteristics?
2. What performance measurement and data analysis methods are best suited for evaluating the program?
3. How can the program characteristics be described in terms of program inputs and outputs for performance analysis?

4. How can environmental managers use these study results and recommendations to evaluate and improve performance?

5. What procedures (e.g., computer models) can be recommended for use of the selected analysis method?

6. What recommendations for operational use or improvement do analysis results suggest?

Operational Definitions

In answering the research question and evaluating the performance of the Air Force environmental program, the following operational definitions will be used:

Performance - overall manner in which an organization fulfills its intended purpose as measured against some standard.

Productivity - a combination of efficiency and effectiveness.

Efficiency - producing the greatest results with a given set of resources (measured in terms of output/input).

Effectiveness - the ability to accomplish the correct organizational tasks.

Input - resources going into an organization.

Output - products or services of an organization.

Environmental Planning Function (EPF) - the function, usually located in Environmental and Contract Planning, which has primary responsibility for the base environmental protection program.

Decision Making Unit (DMU) - the organizational element, in this case the EPF, which will be analyzed.

Scope and Limitations

The scope of this research is limited to investigating and proposing methods for managers to evaluate the performance of Air Force environmental programs. No base-specific recommendations for program or organizational changes will be made. Therefore, these research results should be used as techniques to evaluate organizational productivity, not to penalize or threaten organizations.

Assumptions of the research are:

1. The input and output data supplied by the Air Force Civil Engineering organizations are valid and accurate.

2. The ultimate goal of the environmental program is to protect the environment and ensure regulatory compliance. Effectiveness in striving for this goal should be a higher priority than efficiency or serious consequences for the base and surrounding community could result.

3. The magnitude of environmental requirements have grown dramatically over the last five years. Bases are at various stages in making personnel and budget adjustments to meet these new requirements.

4. The population of interest will not include overseas bases, Air Force Reserve units or Air National Guard units, since their programs are not comparable in size and other ways to most Continental United States (CONUS) bases' programs. Excluding these units does not preclude their benefiting from future application of this research.

II. Literature Review

Background

In the last two decades, productivity has become a growing concern for most organizations in the United States. Productivity growth has declined during this period, with the growth rate decrease starting in 1968 and turning negative in 1979 (40:28). Even with United States trends back to positive growth starting in 1981, nations such as Canada, West Germany, and Japan could surpass our total productivity by the 1990's (1:6; 40:28). A reversal in productivity trends is essential to avoid a severe decline in our economic strength and worldwide political influence (40:28).

Several factors contribute to the national decline in productivity. A major reason is the reduction in this country's market share of technological innovations from 80 to 50 percent (1:5). This decline results in part from our inability to employ enough qualified technical personnel in positions capable of keeping abreast of new technology (1:7). A steady shift from a blue-collar to a white-collar workforce has also altered the productivity growth rate which is measured significantly by industrial production (20:27). Other reasons for more productivity decline include high labor costs with no corresponding productivity improvement, aging factories, increased emphasis on services rather than industrial production, and high unemployment rates (9:5).

Performance Concepts

Before considering the significance of performance to the Air Force, key terms and concepts of performance measurement need to be explored. The following discussion should clarify the ideas that form the basis of the operational definitions stated in Chapter I.

DOD Instruction 5010.34 provides definitions of productivity, effectiveness, and efficiency for use in evaluating overall performance in DOD agencies.

> Productivity: The efficiency with which organizations utilize all types of fund resources (operating and investment) to accomplish their mission represents total resource productivity. The efficiency with which organizations utilize labor resources to accomplish their missions represents labor productivity. (21:1)
>
> Efficiency: Efficient means accomplishing the right things with the lowest possible expenditure of resources. (21:1)
>
> Effectiveness: Effectiveness means accomplishing the right things in the right quantities, at the right times. (21:1)

Productivity depends on both effectiveness and efficiency. In simple terms, it is not only doing the right things, but doing them right (9:10). Efficiency is a ratio of outputs to inputs. It is regarded as the "quantity factor of productivity" and as "the amount of output per unit of input without regard to organizational goals or objectives" (23:17). Effectiveness can be defined as the relationship between work performed and organizational objectives (23:18). It is the quality of having a desired effect (9:10).

Critical to assessing organizational productivity is the need to describe measurable inputs and outputs. Input, or resources consumed, is usually expressed in terms of dollars or manhours and can be relatively easily quantified (1:5). Output, the products or services of an organization, is not so easily quantified. At least products have characteristics which can aid in their measurement: a) Products tend to remain unchanged in contrast to people or organizational arrangements, so their cost can be described with a degree of certainty; and b) Products are usually described in a common language, so they are useful concepts when aggregating costs (30:48).

The concept of productivity has expanded to include not only the quantity, but the quality of output. In more recent times, the emphasis has switched from efficiency to effectiveness. Organizations are now considered "social entities" responsible for quality products, environmental protection, and work place conditions (32:11). Including this quality concept further complicates attempts to quantitatively measure productivity (1:5).

Improving Productivity

Improving productivity is one of the few realistic means of maintaining growth for public sector organizations such as the DOD. With current budget and manpower constraints often coupled with recession and inflation, DOD cannot just raise production to keep up with increasing demands. A key part of the solution is to get more accomplished with available resources; thus, productivity, not production is the main issue. "The public sector must seek continual productivity improvement in order to provide essential services at a minimum cost to the public" (2:16). Substantial gains in productivity are feasible in service oriented organizations which are inherently labor intensive (40:28).

Productivity enhancement efforts are not recent developments in DOD. For example, as early as 1975, DOD established the "Defense Productivity Program in order to bring productivity considerations into the mainstream of defense management" (20:27). DOD Instruction 5010.34 (4 August 1975) and DOD Directive 5010.31 (27 April 1979) were published so that each component would develop methods to improve productivity (11:15-16). Over a billion dollars are invested annually in salaries and expenses for ongoing productivity enhancement programs (2:13). Rather than representing a duplication of programs, the current efficiency review approach "serves as an integrating framework for the various other efforts" (2:14).

Office of Management and Budget Circular A-76 established federal policy that the government shall rely on the private sector to provide goods and services to the greatest extent possible. An activity can be contracted out to private concerns if it is not a restricted "governmental function" and if a cost comparison shows the private firm to be less costly. In 1981, DOD directed each branch of service to establish formal procedures for efficiency reviews of activities not subject to contracting out under A-76 provisions. The A-76 process requires the services to prepare performance work statements which describe work to be accomplished and associated performance standards. Besides getting managers to critically assess organizational goals, functions, and standards, "performance work statements act as a catalyst for new ideas regarding work performance" (2:14). Support for this approach has been proffered by the Government Accounting Office which foresees additional savings possibilities and the private sector which anticipates more contracting opportunities (2:14).

Under the 1981 productivity enhancement directive, each branch of service was allowed to develop its own approach to improving productivity. The Army's initial effort was a decentralized approach with two-man teams assigned to major units. The teams applied various improvement techniques including team-building concepts, goal-setting ideas, and survey-guided development (20:28).

The Navy developed a survey-guided system with teams of experienced personnel operating out of five consulting centers. Team members surveyed communication flow, decision-making processes, supervisory and peer leadership, and work group processes; then made recommendations for each area (20:28).

The Air Force formed the Air Force Leadership and Management Development Center staffed by military personnel displaying exceptional leadership abilities. Teams from the Center visited bases on a routine basis to identify management concerns and to make recommendations to improve productivity through different leadership and management techniques. The teams performed follow-up visits to evaluate implementation success (20:29).

Performance improvement programs have been relatively well established for blue-collar, profit-oriented organizations. As a result productivity gains have been concentrated in non-management, non-professional staffs. For example, 44 data transcribers at McClellan Air Force Base saved the Air Force $26,000 in 21 weeks of a pay incentive program (20:30). These administrative personnel perform "functions" which are relatively easy to describe in productivity terms. In contrast to "tasks" performed by professionals, "functions" are easier to manipulate (e.g., automate) and thereby have more direct influence on productivity (30:48).

Measurement Difficulties in Public Agencies

Even with the emphasis on performance enhancement, DOD takes a deliberate and cautious approach to making organizational changes for productivity's sake. Attempts to improve productivity, often done through increasing automation, have been counterproductive without properly evaluating organizations prior to implementation (30:47). Requisites of a successful program are comparative standards and productivity measurement methods (9:9; 11:16), but these are not well established in the government (11:11).

> Methods for evaluating the relative productivity of decision making units in the public sector have lagged behind similar applications where production functions were more directly obtainable. (5:57)

The measurement difficulty is exacerbated when attempting to use quantitative measurement techniques since public organizations cannot always use a standard evaluation factor, such as dollars, for input and output. To overcome this deficiency, public agencies have tried at least two approaches: a) incorporating appropriate qualitative methods to supplement existing quantitative measures and b) improving or increasing the quantitative methods appropriate for use by nonprofit organizations. The remainder of this chapter reviews the problems that government agencies encounter in measuring productivity, then discusses how improvements can be made using the two methods mentioned above.

Anthony and Young (3:40) elaborate on the classic general difficulties in measuring public agency performance. The availability of a profit measure is probably the key factor in how effectiveness criteria are established in organizations. In a profit-oriented company, success is measured by the amount of profits earned, and managers make decisions on which alternatives produce the largest profit margin. Since military organizations are service-oriented and profit is not a primary objective, management decisions are made on the basis of providing the best possible service with available resources (3:35). Thus, the success of a DOD organization is often hard to determine without profit measures. Additional measurement problems arise because success is often considered to be related to the size of agency budgets and performance data is seldom collected in usable form (31:159).

Research focused on mental health organizations, law enforcement agencies, and regulatory agencies identified several specific impediments to ensuring and assessing productivity in the nonprofit public agency environment.

1. The boundaries of a public mental health agency's responsibilities are not well defined, and the agency usually does not control all mental health activities within its boundaries (4:192).

2. The environment in which public agencies operate is characterized by conflicting public expectations. Mental health agencies commonly do not have a publicly recognized set of outcomes or a consensus on criteria to use in measuring productivity (4). Environmental agency decision-making also must deal with divergent public input, as exemplified by public comments on Environmental Impact Statements. Even though public pressure can affect agency actions, the agency stands alone when its performance is evaluated.

3. Many public sector organizations have poorly defined programs or complex tasks to perform. Public health agencies have difficulties in specifying the optimal type and amount of therapy for patient symptoms (4). A single law enforcement case can involve thousands of bits of evidence and can last for years with concurrent personnel loses (16:210). While most forms of pollution (e.g., chemical spills) are obvious, the consequences and solutions for environmental agencies are not always so clear. The enforcement process for environmental violations is often time-consuming and cumbersome, involving lengthy court cases with complicated evidence (35:170; 36:233).

4. Many agencies' roles are complicated by relationships with organizations at other levels of government. Federal law enforcement agencies have many options in supplementing state and local police even though a case may not be federal responsibility. Federal environmental agencies rely on states for support, but success may reflect a state's regulatory philosophy more than the federal program's effectiveness.

5. A public agency competes with other agencies for limited funds, and various units within the agency compete for agency funds. If Congress stops funds for certain programs, overall agency goals can be hurt. When several federal agencies were responsible for environmental protection, Congress failed to commit adequate pollution control funds because of the diverse agency interests (35:140).

Measurement Incorporating Qualitative Methods

In the 1960's and 1970's, federal agencies tended to rely too much on quantitative measurement and downplayed qualitative matters which contributed to overall performance (14:). The system was popular for many reasons in that (16:214):

1. It was consistent with prevailing systems which stressed computerized manipulation of "hard data."

2. The data allowed program comparisons using increasingly popular cost-benefit analyses.

3. Managers could rationalize resource allocation decisions by citing data analyses.

4. It indicated which agency effort to emphasize by showing which had the best "return for the dollar."

The Federal Bureau of Investigation realized that quantification was being overdone and recognized the following as the system's limitations (16:215):

1. Insensitivity to qualitative considerations such as whether a deadly weapon was used in committing a crime.

2. Encouraging suboptimization by overstating less important crimes merely to show numerical success.

3. Tendency of managers to respond to an artificial "bottom line" created by the quantitative reports.

Many federal agencies started using more "performance evaluations" after realizing that qualitative measures can be used to supplement quantitative measures to better reflect overall organization performance. Performance evaluations are broader in concept than most measurement methods because they describe overall system functioning (i.e., the manner in which a system accomplishes results) while taking into account efficiency, effectiveness, and productivity.

The evaluations better assess the quality of service in an area concerned with human values. On the other hand, quality usually can be secondary to profit or some other "bottom line" measurement in the private sector. Performance evaluation is important for all organizations to assist in tactical and strategic planning, but is necessary for public organizations where efficiency ratings cannot be used as sole indicators of organizational health (14).

By the mid-1970's the Federal Bureau of Investigation had modified its evaluation system to include subjective measures such as inspections by independent auditors, field management assessments, and end-user surveys. The system evolved from a periodic event into more of a reporting process, where many measures are evaluated on a continuing basis (16:217-220).

Many other federal agencies have attempted to maintain a balance of objective and subjective measures in their programs. For example, the Air Force includes Management Effectiveness Inspections, compliance reviews, and independent audits to supplement its array of data analysis reports. For social service agencies, the implementation of Title XX of the 1975 Social Security Act fostered the development of a performance assessment system which combines "quantitative, objective data with more subjective procedures for judging the quality of service" (10:270). And many health agencies consider the subjective measure of user (i.e., patients) satisfaction an excellent indicator of performance (4:204).

Measurement Using Improved Quantitative Methods

While performance evaluation is a worthy concept applicable to public agencies, there are other ways to improve performance measurement. Performance evaluation relies on managers to develop appropriate measures which reflect organizational activity. If these measures can be used as inputs or outputs for quantitative analysis techniques, then the manager's job of performance measurement is made easier. Being able to quantify and evaluate this type of variable requires that agencies obtain better analysis techniques.Performance standards have been developed for DOD operational units which are characteristically blue-collar, profit-oriented organizations. Few performance criteria exist for governmental staff organizations such as legal or other professional offices. The importance of staff offices increases as our society becomes more service and information processing oriented. The demand for DOD staff functions, such as preparing legal briefs and environmental assessments, has grown due to greater technological sophistication and more complex regulations (37:17-18). DOD productivity is not accurately portrayed due to the overemphasis on blue-collar measurement while the white-collar support roles are rapidly growing (37:18).

In 1980, DOD tasked the Navy to develop productivity measures for staff functions. Determining that there was no straightforward method as used for operational units, a Navy task group developed a multi-step approach based on "variance technique" (37:18). Thirty items of performance deviation in nine key areas (e.g., "fuzzy or unclear tasking") formed the basis for the performance standards. Staff performance was then evaluated by how much operations deviated from the ideal. Besides providing the benefit of better identifying individual job requirements and organizational performance goals, the project demonstrated the feasibility of developing staff productivity measures. However, there are limitations to the study since the measures' "appropriateness and validity within any one unit or across multiple staff units need further investigation and testing" (37:21).

The Navy has sponsored research into other areas involving measuring productivity of staff organizational functions. The "current value human resources accounting" approach focuses on the relationship between the current state of the human organization and future performance. Its goal is to aid decision making by providing information about the effects of organizational policies on the value of human resources (32:185). While it does not establish a directly applicable methodology, the study provides insight into performance measurement of relatively qualitative functions. For example, some output measures (e.g., operational readiness) cannot be easily quantified into monetary terms. The study argues for "analogues to commercial-world accounting notions" which could apply to DOD (32:172). Most importantly, the researchers showed that a system which worked in the private sector could be applied to a public sector organization, the Navy.

As part of its productivity enhancement program, the Air Force is working to accomplish performance evaluations of all functional areas. The Air Force Institute of Technology is assisting in this effort by using reviews as thesis projects. Theses by Donovan (22) and Hitt and Horace (28) assessed the productivity of depot-level maintenance operations at Newark Air Force Station and in the Air Force Logistics Command respectively. The Major Command requested Donovans's research in order to find a model to measure "total factor technical productivity" which could be applied command-wide (22:6).

These research efforts involved measures of relatively quantifiable data, but other theses have been completed in areas which are more difficult to measure. Fisher (23) evaluated the Civil Engineering organization which is service-oriented and usually more difficult to quantify than maintenance operations. Byers and Waylett emphasized the difficulty in defining public sector productivity, especially for military fire departments (11:17). All of these efforts relied on analytical tools, Data Envelopment Analysis and its successor Constrained Facet Analysis, which have been shown to be effective in evaluating qualitative data found in staff functions.

Date Envelopment Analysis (DEA) was developed specifically for not-for-profit organizations where it is important to evaluate "program efficiency" and "managerial efficiency" (5:57). The early use of DEA was to evaluate the productivity of schools. In contrast to previous regression methods which compared the relative effects of variables on achievement, DEA compared school units relative to their input and output efficiencies. Using DEA, researchers were able to identify 1) inefficient school units; 2) input and output variables contributing to inefficiency; and 3) changes in the inputs and outputs required to make the unit efficient (5:71). The inability of DEA to provide planning information prompted the formulation of a new method of calculating efficiency called Constrained Facet Analysis (CFA) (22:8).

Successful Application of Productivity Programs

Two elements appear to dramatically affect the success of a performance enhancement and evaluation programs--people and perseverance. Regardless of which approaches are used to measure and improve performance, people are essential to implementation. Performance gains result only from changes made to individuals and organizations (9:9). While productivity strategies may "draw the distinction between management productivity and that being managed," all levels of personnel can benefit (40:32).

> Research and experience both demonstrate that improved productivity and performance depend on not only workers' attitudes and abilities but to a great extent on the attitudes and abilities of management as well. (20:31)

An organization must persevere to keep from losing productivity and individual involvement (9:14). To sustain this drive, organizational goals and objectives may need to be modified to reflect environmental changes; therefore, the performance model should be periodically run to make new assessments of changed measures. Circumstances may vary, but the results of these evaluations and the objectives to be reached usually should be shared with the keystone of the organization--individuals.

The path for future performance evaluation efforts appears to lead toward increased analysis of staff organizations in the public sector. Analytical models, such as DEA or CFA, have successfully been applied to situations where traditional productivity methodologies were unsuccessful. Even though approaches to measuring and improving performance in the public and private sectors may differ, it is important that the government learn from successful commercial efforts. In this regard, DOD has studied private sector performance incentive plans with the objective of determining applicability to the services (20:31). The benefit was primarily for blue-collar organizations, but similar efforts should continue for white-collar organizations.

The Air Force's current review of functional areas has several ancillary benefits.

1. It assists in quantifying staff organizations' inputs and outputs and defining job requirements or organizational goals (37:21).

2. It continues to validate DEA and CFA as effective analytical tools.

3. It provides investigation into private/public sector measurement and techniques.

Finding a methodology that is not only effective but easily implemented by base level units is important, since periodic evaluations are required as program changes are made (9; 20). The results then should be made known to affected staffs, and comparison of relative performance between units may be an important reinforcement technique.

Conclusion

Considering the potential benefits, a review of the performance of Air Force environmental protection functions should be of considerable benefit. At a minimum, the function can benefit from an evaluation of inputs, outputs, and program objectives, since these elements of the environmental program traditionally have not been well quantified. As the price for not complying with environmental regulations rises, base civil engineers and commanders should be increasingly concerned with program performance. This is particularly true because the public now considers businesses and public organizations to be "social entities" with responsibilities for protecting the public and the environment (1:5)

III. Developing Public Agency Performance Measures

Introduction

As discussed in Chapter II, public and service-oriented organizations are more difficult to evaluate than private and product-oriented organizations. A key problem is defining the organization in terms of input and output measures, which depends on a thorough understanding of the organization. Assuming that some of these same difficulties apply to the Environmental Planning Function (EPF), the experiences of public agencies or other service-oriented organizations could be used to determine better ways to evaluate the function. This chapter answers the first and part of the third investigative questions by describing environmental organizations and proposing potential measures.

To assist in developing the measures, the author attempted to research performance measurement accomplished by other environmental organizations (private or public) similar to the EPF, as was done by Byers and Waylett for fire departments (11). Unfortunately, little of the available literature evaluated environmental organizations' performance. One reason for the shortage may be the relative new role of environmental planning offices in business and government. Second, while engineering organizations typically measure the efficiency of production or construction operations, they scrutinize their own engineering functions, including environmental planning, to a lesser degree.

Nonprofit, Service-Oriented Performance Measures

Difficulties in developing productivity measures have been studied in such public organizations as social service agencies, health services, mass transit systems, police departments, and sanitation services. "The fundamental problem stems from the ambiguity of the tasks involved in providing human services and the lack of standard definitions for the array of available services" (10:269). While it is difficult to quantify subjective human factors, Bush proposes surrogate measures for evaluating caseworker productivity.

> The total number of service hours would be one quantitative measure or estimate of input towards goal attainment. Other inputs considered might include caseworker salary and administrative overhead costs. Finally, case closings might be used as an estimate of direct output. The need to consider direct output along with an estimate of consequences on an individual case basis is obvious. The case closing could have resulted from a circumstance other than meeting the designated goal of self-sufficiency. While not a rigorous scientific methodology, such estimates can, in combination, serve as indicators of productivity. (10:273)

The last point about combining measures is critical in that more measures are often needed to represent a subjective activity than in an objective case where number of dollars (input) and number of widgets (output) can nearly represent an entire manufacturing operation.

To facilitate the evaluation of mental health service, Arrington and Biskin (4) add the measurement category of "equity" to the commonly used efficiency and effectiveness. The issue of equity in the availability of services focuses on who the system is designed to service. Difficulties in developing equity measures arise since there is not always a "natural one-to-one relationship between services sought and services available" (4:194). Investing in those patients with the greatest need may not result in the most improvement and subsequent benefit to society; therefore, total number of patients serviced should not be the only indicator of agency performance.

In developing efficiency measures which quantify the amount of health services staff time, the researchers distinguished between programs that required different staff members' activities. Total manhours associated with a service cannot be assumed to represent the same wages and professional training. As general advice for developing measures, the researchers state that the effort should be restricted "to those questions about which reliable information can be developed and in which there is, in fact, management discretion." (4:205)

Public transit is another field in which there has been increasing efforts to deal with performance measurement. "Unfortunately, too little has been done to develop operational definitions of performance, or to identify the weaknesses and biases inherent in certain types of performance measures." (25:379). Since transit revenues in the form of subsidies are increasingly being linked to performance, system survival is partially dependent on accurate measurement.

Two problems often encountered in the transit field are overlapping efficiency with effectiveness and using ratios inappropriately. In contrast to efficiency, effectiveness measures generally should be "cost free" (25:381). Effectiveness ratios are often used without considering the need to also evaluate the overall effectiveness of the function. For example, a bus ridership ratio may indicate System A is "better" than System B even though System B has more total ridership. The resultant claim about System A might be misleading about goal achievement (25:381).

While Gleason and Barnum did not provide ideas for measures specifically applicable to the EPF, their general advice was provided.

> The exact set of performance measures chosen should be based on objectives of the use, should measure all objectives, and should include elements which are controllable by the system. There are no performance measures universally appropriate, and multiple measures must be used. (25:385)

The author's review of the literature attempted to examine private environmental organizations for ideas on their measurement efforts. Since no articles were found, the review moved to the analysis of engineering organizations. Much of the engineering literature focuses on the productivity of production or construction operations which have convenient, discrete measurement units such as manhours and bricks. However, the engineering management field has studied areas which have characteristics similar to those of environmental planning functions.

Based on a survey of engineering executives, there is high potential for engineering productivity improvement in planning and scheduling and a moderate potential in communication and engineering (13:40). Case histories researched by Hensey and Gibble (27) generally support this survey and explain how productivity can be increased in these areas by improving performance reviews and feedback mechanisms. Identifying where and how to make productivity improvements requires measurement capabilities.

The "hierarchy model," developed for the construction industry, provides measurement capability for these engineering management areas. The model allows continuing analysis of construction "productivity flow from project conception to completion," and addresses all industry levels, including policy formation, program management, engineering, and site construction (29:138). By reducing a construction project to its basic components, the hierarchy model and its measures fully describe the total productivity expression. Suggestions for measure development based on experience with the model include a) concentrating on measurement of effectiveness versus efficiency, b) maximizing measurement of total productivity versus component parts, and c) attempting to use measures applicable to similar types of decision making units (29:142-143).

As the cited experts have stated, establishing the criteria, or measures, by which performance is measured is an important initial step in performance measurement. Table 3.1 is a summary of guidelines for establishing measures proposed by several authors of the articles which were researched.

Potential Measures for Environmental Agencies

This section evaluates *regulatory agencies*, with emphasis on the Environmental Protection Agency (EPA), to determine their performance characteristics. The analysis shows similarities between regulatory agencies and the EPF in anticipation of applying some of these agencies' measures to the EPF.

Agencies' roles are to provide goals, standards, pricrities, and monitoring and administrative systems to carry out their legislated purpose. They can use economic incentives for regulated firms to comply and administrative methods for resolving disputes (17:450). The system in which an agency operates affects its performance and what it

TABLE 3.1

Guidelines for Establishing Performance Measures

1. Seek substitutes for "profit" which can be measured and analyzed (34:10). For a public agency this might be equivalent to net income or operating surplus (31:175).

2. Initial attempts at developing organizational measures might include project completion and timetables (31).

3. Consider using "result" measures as opposed to "process" measures. Results measures are better because they are readily observable, reflect the quality of work, are congruent with organizational objectives, and emphasize end results (3:520; 31:163).

4. Ensure there is a variety of measures (10:273; 25:385). Agency performance, evaluated using only a few mechanisms, may actually be declining while indicators show a positive trend (41:73).

5. Attempt to make measures applicable to organizations with similar operational characteristics (29:143).

6. Performance measures should be established using input of personnel at the decision making unit level (31:160).

7. Measures should be limited to those for which reliable information is available and management has the ability to control (4:205; 25:385).

8. Keep a balance between effectiveness and efficiency measures when possible (29:142). Effectiveness measures should be "cost free" (25:381).

9. Candidate measures should meet certain criteria when using a quantitative model such as DEA and CFA (6).
   a. Outputs represent important DMU goals.
   b. Measures apply to DMUs under consideration and exist in non-zero amounts.
   c. Inputs represent resources used by the DMUs toward attaining outputs.
   d. Changes in inputs will result in corresponding changes in outputs.
   e. The magnitude of physical input and output quantities is represented.
   f. The input and output quality are represented.

can use for measurement. In the broadest sense, agency performance is judged by how well public interests are protected. The regulatory agency is a collection of Decision Making Units (DMUs) which are responsible for various clients, some of them with divergent viewpoints. One agency goal is to satisfy clients without antagonizing competitive interests (38:58). See Figure 3.1 for an overview of the system in which the EPA operates.

There are 3 main clients of the EPA (see Figure 3.1) which have an influence on how the agency is evaluated.

1. Public - The public is the ultimate determinant of the regulatory approach, yet it may lose interest when dealing with technical matters. As the public's affluence increases, they expect more of government to improve the living standard (41:11).

2. Interest Groups - The public commonly provides input through and support to "institutionalized" interest groups which can deal with technical issues. The groups have become more sophisticated and changed their focus to specific, subtle forms of pollution (41:12).

3. Regulated Community - Most regulated organizations prefer to have comprehensive, well-enforced regulations so less conscientious organizations are not given advantages (17:451). Regulated entities evaluate the EPA in this regard and whether pollution control hurts economically.

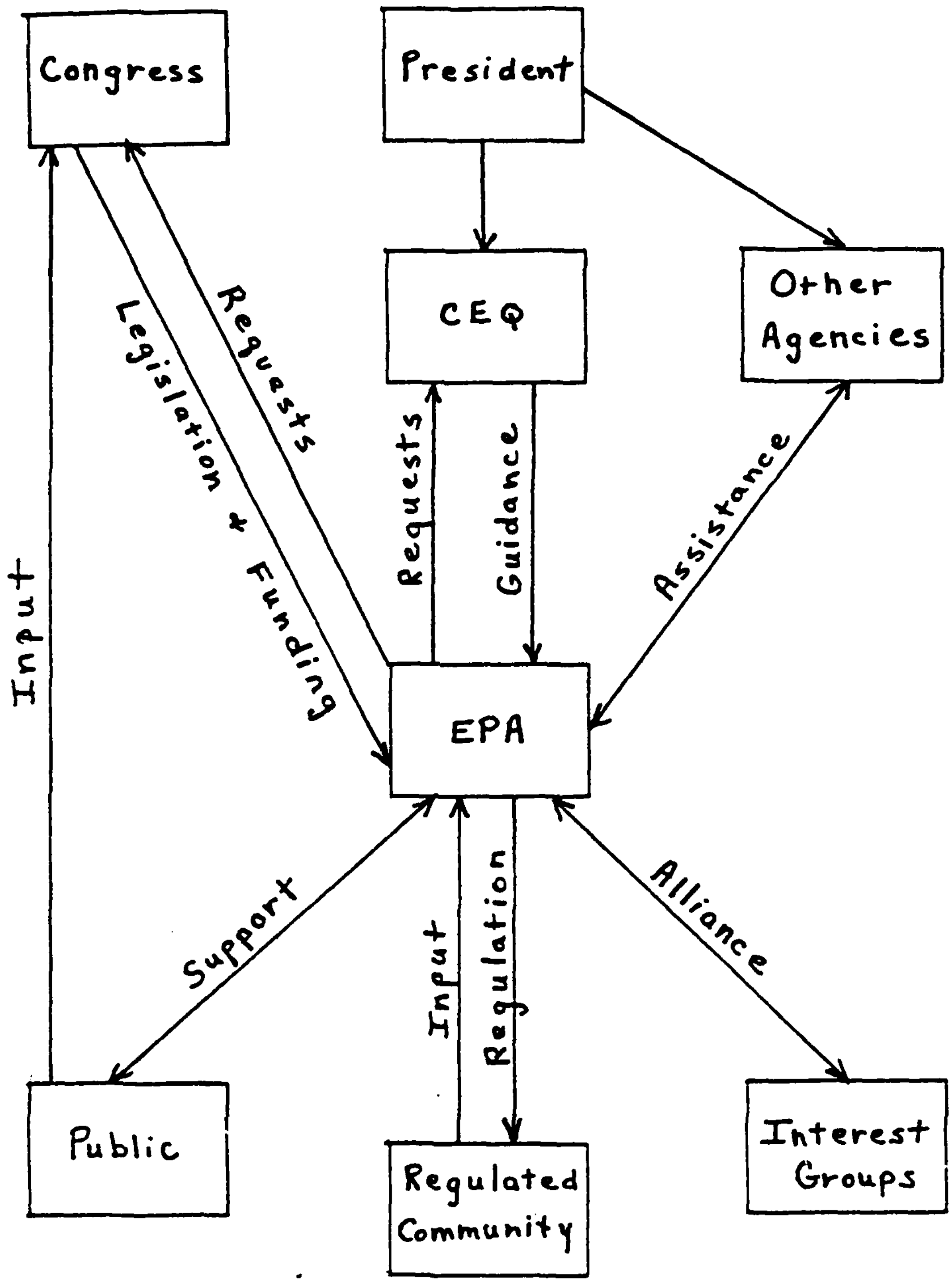


Figure 3.1: EPA Regulatory System

Similarly, the EPF has the responsibility of ensuring that base organizations comply with EPA and Air Force environmental regulations. Various methods of enforcement are available, including working through committees, threatening potential EPA involvement, or elevating to the base commander. The EPF is in the tenuous position of not only assisting and advising, but attempting to regulate other organizations.

The EPF has clients similar to the EPA's, such as a regulated community (e.g., maintenance) and allies (e.g., bioenvironmental engineering). The EPF has to deal with the public and the base population, although their interest is usually only piqued when something goes wrong. Recently interest groups have shown more interest in DOD as base environmental situations are increasingly publicized. The EPFs are often confronted by public and interest group coalitions. See Figure 3.2 for an overview of the EPF system which is analogous to EPA's.

Chapter II listed some performance measurement problems of public agencies. The EPA and other regulatory agencies are confronted with additional conditions which affect their ability to perform as expected and to measure this performance. Analogous conditions exist for other environmental organizations such as the EPF.

1. Government Emphasis - Various federal administrations place different emphasis on regulation and

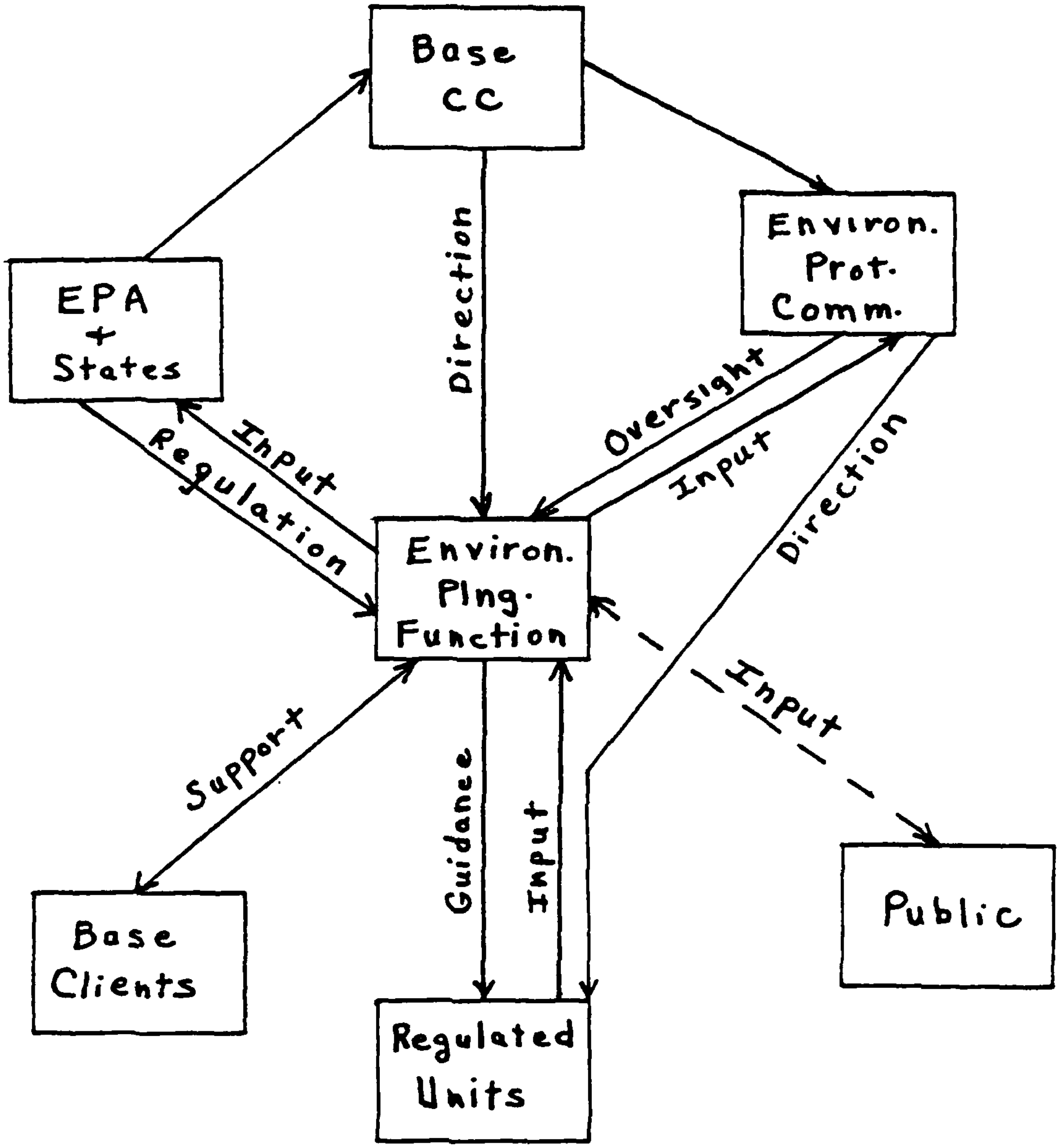


Figure 3.2: Base Regulatory System

environmental matters, so the EPA may need other enforcement means, such as economic incentives, to ensure effectiveness (17). Reduced government emphasis on regulation may make the EPF job easier, unless the deemphasis results in less EPF funds.

2. Form of Output - Regulatory agencies predominately provide services which are not readily measured. Some other public agencies are more product oriented, such as the Tennessee Valley Authority which produces electricity (36:247). The EPF also provides a service, not a product as a maintenance organization does.

3. Change in Agency Role - the EPA's performance is difficult to track considering the frequent changes in mission goals and enforcement methods. For example, the Agency has vacillated between an adversarial and ally role in its relation with business (33:165). The EPF's role changes with changes in its parent agency and in the EPA's regulatory approach.

4. Difference in Agency Programs - the EPA's programs vary in their suitability for measurement. The enforcement program is relatively "soft" compared to the grant program which provides funds for building wastewater treatment plants (24:126). The EPF experiences similar problems in comparable base programs.

5. Politics - Regulatory agencies are in political environments where vagueness is often preferable to clarity.

Publicly defining specific organizational performance may offend someone internal or external to the agency (1:6; 31:161). The EPF must deal with politics on and off base in the volatile environmental area.

Developing measures is not an easy task for environmental organizations considering all these performance related difficulties. "Trial and error" has been the development technique for many organizations. One public utility's approach to being publicly responsible was to develop "supplemental measures of performance." For environmental quality, they measured actions taken against the firm, including number of lawsuits and amount of fines (31:154). Lawsuits were soon dropped because the utility had little control over someone wanting to sue.

The EPA has found it desirable to have a variety of enforcement options that range from gentle incentives to severe penalties for criminal violations. (33:132). In the 1960s, the government relied on legal enforcement of stringent pollution standards. By the 1970s, the poor success of the earlier approach caused support to switch to other enforcement methods (36:231). Shifting focus to economic incentives, such as effluent charges, reduced the number of enforcement cases. (24:130). The EPA was able to increase efficiency while still effectively reducing pollution. Thus, numbers of violations issued may not always be a good performance indicator (by itself) for EPA.

In 1982, the EPA shifted to an enforcement program which relies on "managing for environmental results" (19:605). The quantitative methods were balanced with reports of how effectively managers' actions serve to protect the environment. The three main aspects of the program are an accountability system, environmental management reports, and indicators of environmental results (19:605). The accountability system and the management reports are similar to performance evaluations discussed earlier.

Of primary interest are the indicators of environmental results which represent an attempt by the EPA to improve objective measurements. "Programmatic indicators" are paperwork actions taken by the Agency, such as permit revisions or violation issuances. "Ultimate impact indicators" include number of pollution incidents or amount of air pollution reduction obtained. While the ultimate indicators are not as easily obtained, the EPA's attempts to use the best combination of data available to see if environmental objectives are being met (19:605). However, results measures are often difficult to evaluate when considering the impact of the program, not just the output (3:564). For example, reducing emissions from smoke stacks is an output relatively easy to measure, while long term impacts of reduced air pollution are difficult to measure.

As part of this new regulatory approach, the EPA developed an "environmental auditing" program. The program, which many private companies and public agencies already use, takes a snapshot of compliance status at a given time. Audits are considered a more efficient means of ensuring compliance because infractions are caught early before serious consequences occur (18:509). While audits could be characterized as performance evaluations, they contain measures such as out-of-compliance pollution control equipment which can be quantitatively analyzed. Ultimately the success of an environmental function is measured by its performance during audits. Developing measures and periodically evaluating them prepares an EPF for such audits.

The above discussion provided some general guidelines for establishing productivity measures to be used by public agencies. Some specific output measure candidates for the EPA or other environmental agencies are listed at Table 3.2. (Input measures are not considered because they are fairly standard among organizations.) Some of the output candidates, which could be modified for EPF use, are considered in Chapter V.

Conclusion

Ironically, much of the literature appears to be on how to increase productivity with less emphasis on measuring

TABLE 3.2

Possible Environmental Agency Output Measures

1. Funding level, percent increase or percent of requested amount (31).

Organization cannot function without proper funding. Shows how well EPA lobbies Congress and constituents for support.

2. Monitor and improve environmental quality (26:169).

One of EPA's responsibilities under federal law. Difficult to measure as stated.

3. Number of monitoring reports or compliance measurements.

Alternative to above which is more easily measured.

4. Fines and penalties assessed (26:170).

If firms do not comply, then this measure reflects EPA's ability to assess penalties. Ultimate goal of measuring environmental quality might not be reflected.

5. Number of Violations Issued (33).

Necessary when enforcing compliance with environmental standards. Excessive number (too many violators) may indicate something is wrong with the approach.

6. Dollar loss from environmental degradation(24; 35).

Indicates trend in overall protection program. It is difficult to measure or place dollar figure on loss.

7. Project/program completion times (31:175).

A rather fundamental concept of attempting to complete projects on time. It is appropriate for new programs or other situations where measures are not well defined.

8. Amount of inter/intra-agency coordination required (31:176).

Measures amount of communication between or in agencies which prevents program overlap. Relates to efficiency of providing government services, but appears difficult to measure.

TABLE 3.2 (Continued)

9. Input effectiveness (38:57).
Number of internal messages needed to solve a problem.
10. Processing capacity (38:57).
Average waiting time per message.
11. Agency responsiveness (38:57).
Client satisfaction index combining waiting time and agency response.
12. Number of case closings (10)
An example for the EPA would be the number of compliance investigations completed.

what is to be improved. Many articles disregard what measures are to be evaluated and how performance measurement will be accomplished. Obviously these are key aspects when looking at such management functions as scheduling and communication. Improvement can only occur when there is an understanding of what aspects are deficient and when to concentrate work on a specific area.

The nature of regulatory agencies makes performance measurement difficult. Regardless of the problems, it is important that agencies have some type of evaluation program and attempt quantitative measurement. Measuring means emphasizing program goals and priorities by attracting attention to what management considers important. "Any measure is imperfect. As long as the end result--the goal--is clear, however, almost any measure is acceptable." (31:174).

IV. Methodology

Overview

As discussed in Chapters II and III, productivity measurement in public organizations is a complex problem. Multiple-inputs, multiple-outputs and few tangible outputs make evaluations of service-oriented Air Force Civil Engineering organizations difficult. Further complications arise when assessing the Environmental Planning Function (EPF) because of its broad charter (e.g., protect the environment).

In approaching the problem of evaluating EPF productivity, these investigative questions need to be answered:

a. Of the measurement models available (such as regression, ratio analysis, Data Envelopment Analysis, and Constrained Facet Analysis) which provides the best method of analyzing EPF performance?

b. What constitutes a set of inputs and outputs to form a complete representation of Air Force EPF performance?

After discussing the analytical models, the chapter will provide a methodology for specifying and identifying candidate EPF input and output measures. A data collection plan and proposed procedures for accomplishing the data analysis are outlined.

Selection of Analysis Method

Few analytical models compare multiple inputs to multiple outputs while accounting for the interaction of these variables. Data Envelopment Analysis (DEA) developed by Charnes, Cooper, and Rhodes (12) accomplishes this complex analysis, making the use of multiple variables more meaningful. Bessent, Bessent, Clark and Elam (7) refined DEA into the more advanced CFA model. DEA and CFA have been rated superior to regression and ratio analysis, exemplified by their success in evaluating school systems and Air Force organizations as noted in Chapter II (5; 11; 28). The next three sections discuss the operation and attributes of DEA and CFA and explain why they were selected as the appropriate model for evaluating EPFs. A brief comparison of various analytical methods is found in Appendix A (14), and several theses (11; 23; 22) provide more details on these methods.

Data Envelopment Analysis Operation (15)

DEA was developed to evaluate the relative efficiency of public sector organizations performing similar type functions. Using a computerized linear programming model, DEA can evaluate multiple inputs and outputs and their interrelationships simultaneously. The model generates an efficiency rating for each organization, designated a Decision Making Unit (DMU), compared to the other organizations (DMUs). DEA compares all DMUs to locate the best performing units, those which produce the greatest output from the least input. Then the model compares the remaining units to the best units and provides a single aggregate measure of relative efficiency for each DMU. The highest possible rating a DMU can achieve is 1.0 in comparison to the other most efficient units. Since the rating is an input/output ratio, the less efficient organizations will have a rating less than 1.0 and greater than 0.0 (15).

Figure 4.1 is a simplified two-dimensional comparison of DMU efficiency using DEA. Each unit has two inputs (X1 and X2) and one output (Y). DEA reduces the DMU inputs by the amount of output each produces so that all output values are one (1.0). Each DMU is plotted according to its input/output ratio--X1/Y on the abscissa and X2/Y on the ordinate. The more efficient units are closer to the origin since they use less input (X1 or X2) for a given output (Y). A, B and C are given ratings of 1.0, while D is rated less than 1.0 in comparison to A, B and C. This comparison is accomplished by drawing a line between the most efficient units (i.e., a frontier) and comparing D to the line. D's rating is the line sector OQ value over the line sector OD value. In this case, the ratio is approximately 3.5 (OQ) divided by 5.0 (OD) for an efficiency rating of 0.70.

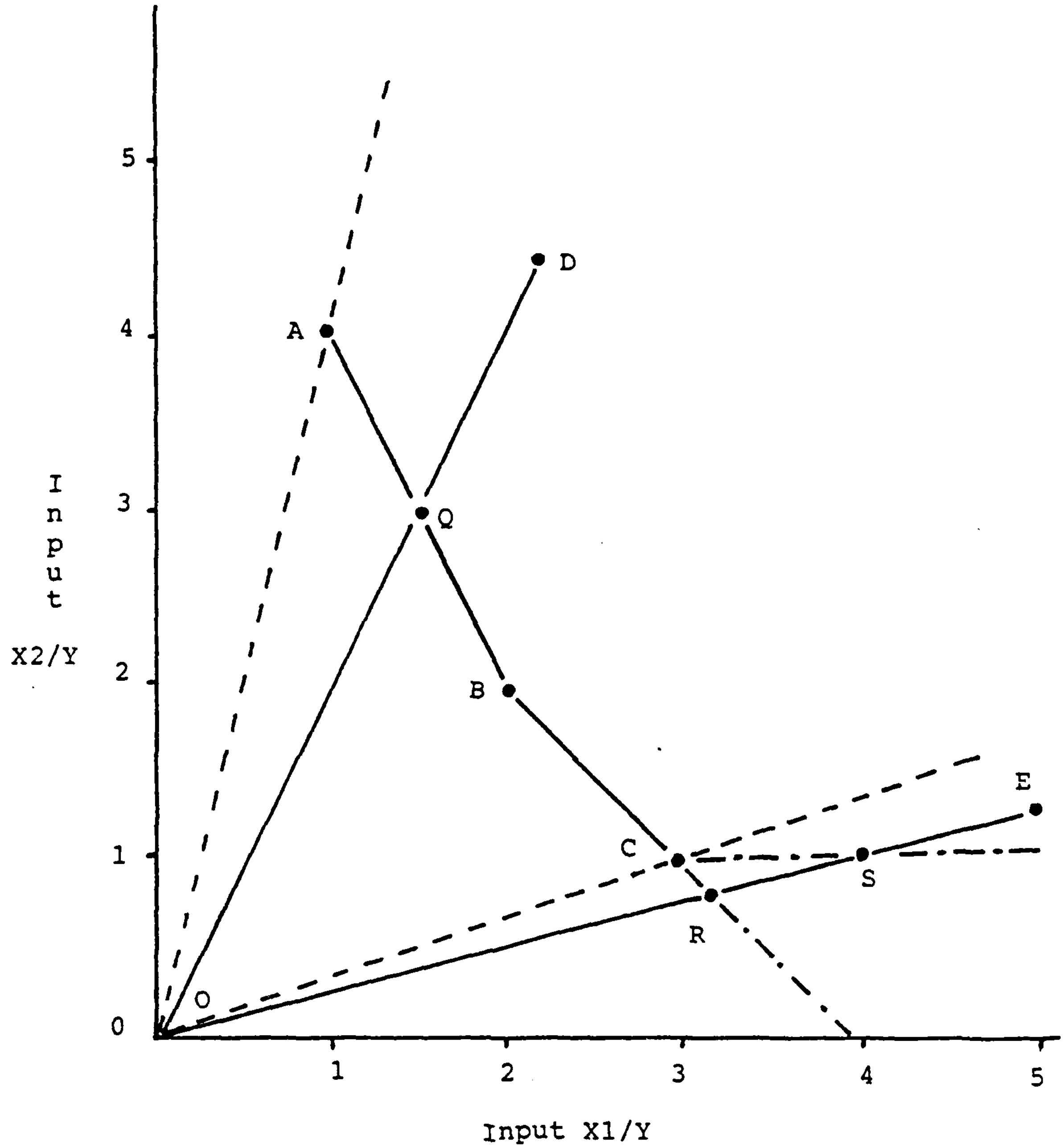


Figure 4.1: Relative Efficiency of One Output, Two Input Organizations

Other benefits of DEA include its scaling and weighting characteristics. The model is able to compare multiple inputs and outputs of a DMU without having them in a common scale or unit of measurement. This is accomplished by comparing the same measures of one DMU to the same measures of other DMUs. As pointed out in Chapter III, non-profit DMUs cannot use solely monetary comparisons, so the scaling characteristic is important. Also, the model does not require a prior weighting of the measures according to their importance. Instead, the model derives from the data what weights should be assigned to each measure. These weights can be used to identify DMU inefficiency and DMU measures which can be changed to increase efficiency (7).

Constrained Facet Analysis Operation

The CFA model is an extension of the DEA model, designed to eliminate the DEA limitations. DEA's primary limitation is the inability to fully explain (i.e., envelope) all DMUs, giving some units inflated efficiency ratings (7). DEA can rate a DMU's efficiency in comparison to a "neighborhood" of the most efficient units. However, any unit which does not have a comparable mix of inputs and outputs to the neighborhood will not be evaluated. DMU E in Figure 4.1 is an example of a DMU not enveloped by DEA. Since the ray from the origin to DMU E does not cross the relative efficiency frontier, DEA cannot determine its relative efficiency (14).

CFA goes beyond the initial step of identifying the efficiency frontier and the relative DMU efficiencies. CFA goes through an iterative process of comparing less efficient DMUs with those along the efficiency frontier. For those units which do not have a facet of the frontier to be compared against, CFA "extends" the facet so that the unit can be compared against units with similar mixes of measures. Facet A-B-C has been extended beyond C by CFA in Figure 4.1 to envelop DMU E and compare it to other DMUs. DMU E is compared to point S for an upper bound value and to point R for a lower bound value. Thus, CFA attempts to rate a DMU with estimates of efficiency even if a DMU has an input or output mix which causes it to be unbounded by the relative efficiency frontier. The value of the information to managers is enhanced since inefficient DMUs of various input/output mixes can be compared to at least somewhat comparable units (14). Because of CFA's capability to make more organizational comparisons, this research will attempt to use primarily CFA for data analysis.

DEA and CFA Attributes

The following is a summary of DEA/CFA attributes which make the models desirable for comparing public organizations (14; 22:24-25):

1. The models compare multiple inputs and outputs simultaneously providing single aggregate ratings (ratios).

2. Efficiency frontiers are based on empirical data rather than on preassigned ideals.

3. "Neighborhood" comparisons ensure that DMUs are mainly compared to units with similar measures.

4. The models are less biased because weights reflecting value judgments are not assigned *a priori*.

5. The models indicate output shortages and input overages so that corrective actions for inefficient DMUs can be taken.

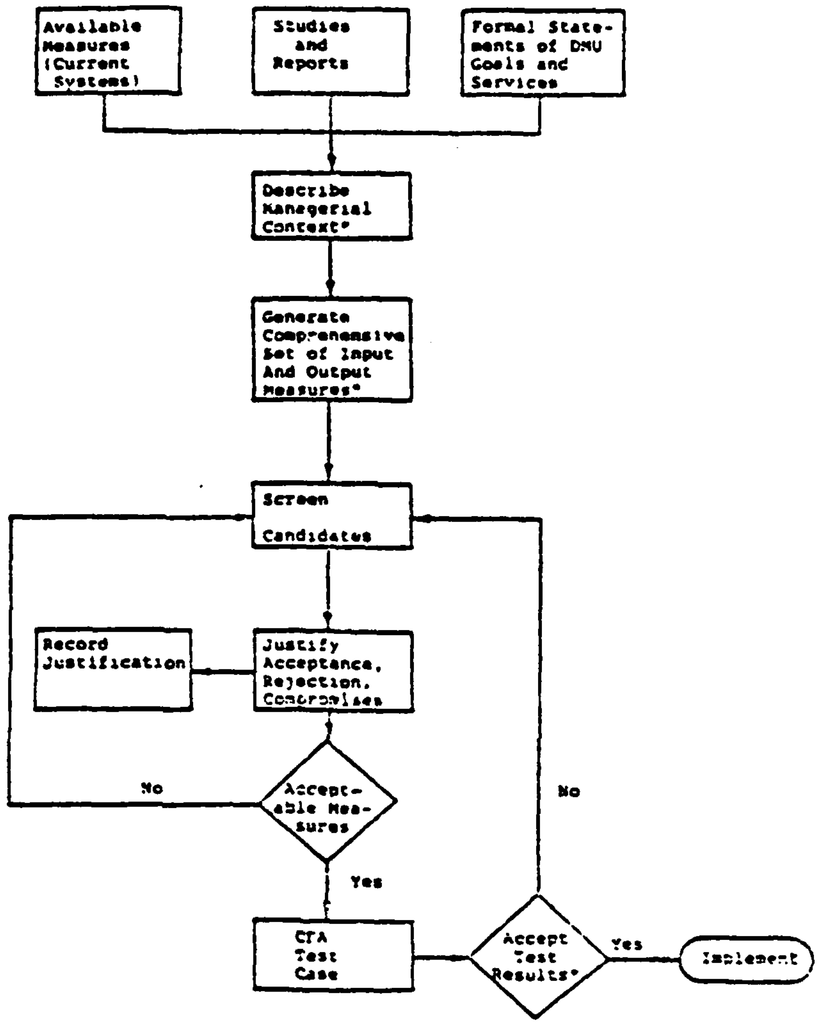
6. The models handle non-commensurate measures which are frequently found in non-profit organizations.

7. The inefficient units are assigned the highest possible efficiency rating, giving them the benefit of doubt concerning measurement error.

8. CFA attempts to rate all DMUs by providing an approximate comparison frontier for unbounded DMUs.

Input and Output Measures Selection Process

A critical step in analyzing productivity is the specification of candidates as input and output measures. This research attempted to find quantifiable measures, easily accessible to managers, that can be used to assess their units' productivity. Development of EPF measures followed a formalized identification and selection methodology developed by Bessent, Bessent, and Clark (6). The remainder of this section follows the methodology flowchart at Figure 4.2.



* These Activities accomplished by CFA specialists in concert with the managers and analysts responsible for monitoring and controlling DMU's.

Reprinted from <u>Specification of Inputs and Outputs in Data Envelopment Analysis</u> (6)

Figure 4.2: Specification of Inputs and Outputs

The initial row in the flowchart, describing current information available, is important to thoroughly study because of the nebulous nature of the DMU under investigation. "Available Measures," "Studies and Reports," and "Formal Statements of DMU Goals and Services" form the basis of understanding the EPF operations and lead to a description of the managerial context (next block in the flowchart). The managerial context is that aspect of the DMU's overall function which is to be evaluated.

The next step is to generate a comprehensive set of input and output measures based on the managerial context. Providing a comprehensive list of potential measures is important for success in modeling since omission of a critical input or output could distort results. Screening of measures for duplications or inappropriateness occurs in the next step.

According to the flowchart, the measures should be tested after an acceptable set has been established. Unacceptable results indicate a need to find more measures or modify existing measures (assuming all steps were correct to that point). In essence, this research is providing these testing and analysis steps and, if successful, will result in a set of measures for future use by EPF managers. Chapter V actually steps through the flowchart to arrive at an acceptable list of EPF measures.

Data Population

The population for this research is the CONUS Air Force installations under eight Major Commands. Wide variability exists among installation missions and environmental protection programs. AFLC's depot-level maintenance activities overshadow most smaller bases in environmental significance. Regardless of the variability, this set of installations was selected for several reasons. First, it was important to examine these measures to determine if they apply to all bases regardless of size. All Air Force installations have the same objective of environmental protection, and consequently should have similar measures. Secondly, Headquarters Air Force receives environmental status reports from all CONUS installations. Parts of these reports form the basis for some of the measures. Validating these measures means Air Force can use the status reports and the corresponding measures for comparisons of all installations.

The third reason has to do with the number of observations needed for DMU efficiency analysis. The CFA model requires a minimum number of observations to establish an efficiency frontier. The rule of thumb is that observations should be twice the number of input and output measures. If all the installations reply, a total of 85 observations will be available for analysis, allowing 42 inputs and output measures to be used in the CFA analysis.

Even though all the measures may not be used as variables for each analysis run, the more measures used the better the characterization of the DMU. Therefore, using most of the CONUS installations will allow the use of a greater number of measures to describe EPFs.

The selection of the EPF as the DMU was done to confine the analysis to a DMU with a set of related objectives. The other functions within the Environmental and Contract Planning Section have responsibilities dissimilar to the environmental and resource protection responsibilities of the EPF (see Figure 4.3).

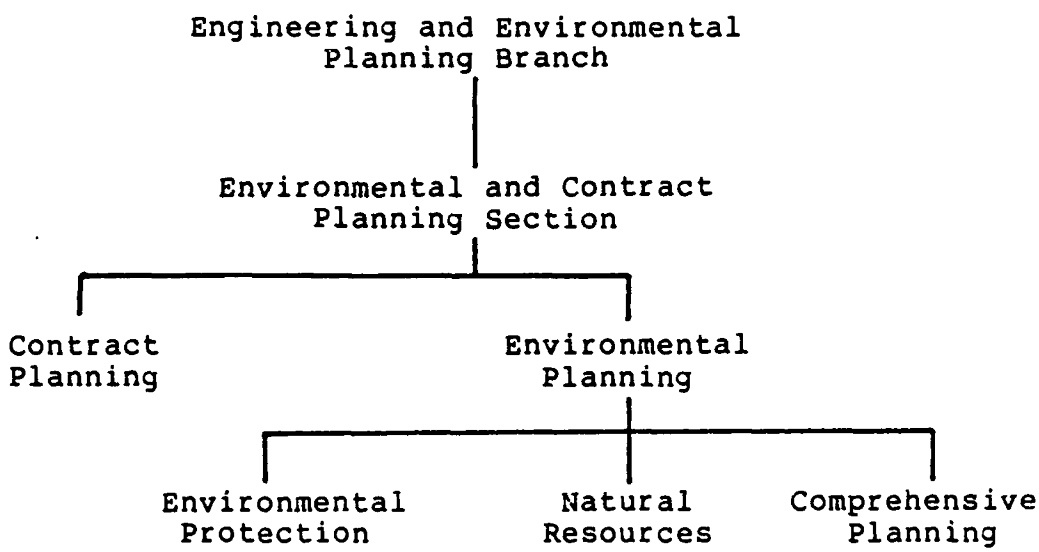


Figure 4.3: EPF Hierarchy

The contract planning function has few, if any, of the same objectives as the EPF. The comprehensive planning function has many responsibilities, such as Air Installation Compatible Use Zone, which would require more measures to analyze. The key point is that the jobs within Environmental and Contract Planning are so diverse that too many variables (measures) would be required to adequately describe the Section and still use the CFA model effectively.

Use of the DEA and CFA Models

DEA and CFA were selected as analysis models so that multiple inputs and outputs needed to describe EPFs can be analyzed. The models will identify the inefficient DMUs and inputs and outputs which contribute to the inefficiency. The models take into account the interactions between variables. The significance of each input and output variable is determined by the models and will be unique for each organization. Weights do not need to be assigned to the variables since the weights are determined by the models when they assign multiplier values to the inputs and outputs.

Using surveys, data will be solicited from 85 installations regarding the measures chosen to be analyzed. The data will be analyzed using the computer program, Productivity Assessment Support System, which is an "integrated system for performing productivity analyses [DEA and CFA] for units that utilize the same kinds of inputs to produce the same kinds of output over the same period of time" (8). Productivity Assessment Support System is written in dBase III computer language and operates on an IBM-AT. Since the system is restricted to 20 variables, not all measures can be compared during each run. Depending on the analysis desired, either some of the compatible measures will be combined before a run or only selected inputs will be compared against selected outputs during a specific run.

The analysis results must be interpreted for application to the function, since the models cannot explain what caused the measure's inefficiency or how to correct it. After analyzing the data, the research will evaluate whether the models can be used to provide information to managers for improving their EPFs. Inefficient installation units may be able to change the input surpluses or output shortages for measures identified by the models. Headquarters Air Force or Major Commands may be interested in what general performance problems are confronting the installations.

Summary

This chapter answered investigative question 2 by evaluating analysis methods and selecting the DEA and CFA models as the desired technique. It further discussed how

DEA and CFA would be used for analyzing EPFs from CONUS installations which were selected as the data population. As an initial step in answering investigative question 3, the discussion covered the methodology to be used for selecting DMU measures. Chapter V discusses how the input and output measures were selected, then narrowed to the number and type which best represent EPFs and best suit the models' capabilities.

V. Selection of Input and Output Measures and Data Collection

Introduction

This chapter describes the process for selecting the candidate EPF measures and refining that list to the measures which most accurately portray EPF operations. The selection process will follow the procedure (6) described in Chapter IV. The refinement process involved the expertise of Air Force personnel familiar with EPFs. Developing measures was an iterative process requiring numerous revisions, since few efforts have been made to characterize the EPF in objective terms such as inputs and outputs. The chapter finishes by describing what data were needed for the selected variables and where the information was obtained. This fulfills investigative question 3.

Information Available for Measurement Development

Reviewing available measures, DMU goals and services, and DMU studies and reports helps to describe the managerial context leading to the generation of a list of measures (see the flowchart at Figure 4.2). Chapter III addressed the first item by reviewing measures which could reasonably be applied to the EPF. This section describes EPF goals and services, EPF reports, and the EPF managerial context.

As an implementing document, Air Force Regulation 19-1, Pollution Abatement and Environmental Quality, established the formal environmental protection program. AFR 19-1 "states and assigns responsibilities for the development of an organized, integrated, multidisciplinary, environmental protection program to make sure that the Air Force conduct its activities in a manner that protects and enhances environmental quality" (39:1). The regulation emphasizes that Air Force policy is to comply with not only the letter but the spirit of federal, state and local environmental laws and regulations. Further, Air Force installations are expected to demonstrate leadership in correcting environmental ills, controlling pollution, and more importantly, reducing actual or potential causes of pollution (39:2). Thus, the overall goal of environmental protection is not to increase production of a product, but to increase service for the agency to be in compliance with environmental regulations. To meet the objectives of this goal, the Air Force is avoiding pollution of the air, land, and water. In a sense, the objectives are comparable to cost avoidance objectives.

Current means of documenting Air Force environmental performance are limited primarily to two formal reports: 1) Pollution Status Report, RCS: DD-I(SA) 1381, and 2) Defense Environmental Status Report, RCS: DD-M(A) 1485. The first report provides the status of pollution abatement projects. The base projects listed in the report are heavily dependent on the age of base facilities and on the base mission; therefore, the report is a poor indicator of overall EPF functioning.

The Defense Environmental Status Report is structured to show how well the environmental program is meeting the intent of AFR 19-1 and other directives. The report is divided into six environmental programs with goals assigned to each of the following areas:

1. Clean Air
2. Clean Water
3. Solid and Hazardous Waste
4. Installation Restoration
5. Safe Drinking Water
6. Environmental Auditing Management

Appendix B is a complete listing of areas and goals. For the most part these goals represent environmental compliance objectives and methods including operational requirements (such as correcting pollution sources) and administrative requirements (such as applying for permits). Part 2 of the Defense Environmental Status Report addresses management indicators for the various goals in Part 1. Most of the management indicators are comparisons of compliance from period to period, an indication of the importance that the Air Force assigns to avoiding environmental problems.

Another performance evaluation technique being developed by the Air Force is the Environmental Compliance and Management Program. The crux of the program is auditing base programs to determine their compliance with environmental regulations. The program is referenced as part of the sixth Defense Environmental Status Report goal and is similar to the Environmental Protection Agency's audit program discussed in Chapter III. The present evaluation method, as depicted in Table 5.1, only provides a binary (i.e., in or out of compliance) analysis which is not well suited for DEA/CFA. Also, the Environmental Compliance and Management Program is presently only in a prototype stage and comprehensive information would not be available. However, the emphasis by Air Force on implementing the program indicates the importance of using compliance as a success criterion. Further development of the Environmental Compliance and Management Program could eventually result in its use as either a measure or a data source for DEA/CFA.

Environmental protection performance has been evaluated in a general sense for many years as the ability to stay in compliance (i.e., to avoid violations). The semi-annual environmental reports provided this information to headquarters levels. But the base level managers have not had a method to evaluate their efficiency in meeting these standards, especially in comparison to other DMUs. Therefore, the managerial context defined for the efficiency model is the measure of resource utilization in attempting to attain total compliance.

TABLE 5.1

Environmental Compliance and Management Program Evaluation Method

COMPLIANCE SUMMARY TABLE

	Substantially in Compliance*	Out of Compliance
Air Emissions		
fuel burners	X	
incinerators		X
VOC		X
other		
Wastewater Discharges		
sanitary sewage	X	
stormwater		X
industrial wastewater		X
Solid Waste	X	
Hazardous Waste		
accumulation points	X	
TSD facilities		X
PCB		X
Pesticide	X	
POL Management		
SPCC	X	
leaking tanks/pipes	X	
Drinking Water	X	
Hazardous Materials Management	X	

*In compliance with regulatory requirements where a few minor (technical or administrative) exceptions exist.

Identifying Potential Input and Output Candidates

The next step in the flowchart, developing a comprehensive list of input and output candidates, was assisted by the participants of the functional review workshop for the Environmental and Contract Planning Section, 10-14 March 1986. The workshop was one of a series held at Headquarters Air Force Engineering and Services Center, Tyndall Air Force Base, under the auspices of Project IMAGE. The participants identified an exhaustive list of organizational tasks, problems, and potential corrective measures (Appendix C). Based on the results of this workshop and the author's experience in the environmental field, a comprehensive list of inputs and outputs was generated (see Appendix D). Key ingredients in the development were the analysis of measures in Chapter III and the information sources, such as the status reports, mentioned earlier in this Chapter.

Output measures can be classified primarily as either results measures or process measures. Results measures reflect DMUs organizational objectives, while process measures reflect organizational activities. Because the production function for the EPF is difficult to identify, measure, and quantify, process measures were not considered satisfactory by themselves. Many of the outputs were devised as results measures so they would indicate compliance status. A combination of process and results measures helps to thoroughly describe a DMU's activities, although results measures have some advantages as discussed in Chapter III. A similar mix of measures, consisting of programmatic and ultimate impact indicators, was recommended by the Environmental Protection Agency for its programs.

Refinement and Selection of Final Measures

The comprehensive set of input and output measures was presented to the functional review workshop participants to review for completeness and appropriateness. The entire list of candidate measures was screened to justify the acceptance or rejection of any measure. The process involved determining if: a) the measures form a reasonable representation of the key DMU variables to be evaluated, and b) the measures form a realistic description of the DMU's activities. The participants, who have experience from various Air Force levels, provided suggestions for revisions, deletions, and additions.

Final review of the measures list was accomplished by an expert from each of three operational levels--base, Major Command, and Air Force Engineering and Services Center. The input and output list was narrowed down to those measures which best describe the resources and critical operations of the EPF. Some measures were refined or combined with other measures to better reflect the EPF mission without redundancy. The final lists of inputs and outputs are provided at Tables 5.2 and 5.3 respectively. Rationale for dropping specific inputs and outputs is explained in Table 5.4.

TABLE 5.2

Input Measures Selected

1. Total military and civilian personnel costs (dollar value)
2. Total military and civilian manhours (number)
3. Assigned military and civilian personnel (number)
4. Cost of supplies and equipment (dollar value)
5. Contracted services expenditure (dollar value)
6. Air pollution sources (number)
7. Air quality violations received (number)
8. Water pollution sources (number)
9. Water quality violations received (number)
10. Hazardous waste facilities (number)
11. Active solid waste landfills (number)
12. Solid/hazardous waste violations received (number)
13. Hazardous waste generated (quantity)
14. Environmental permits required (number)
15. Natural resources management plans and cooperative agreements (number)

TABLE 5.3

Output Measures Selected

1. Total documents reviewed (number and manhours)
2. Total reports prepared (number and manhours)
3. Environmental compliance inspections performed (number and manhours)
4. Responses to environmental incidents (number and manhours)
5. Environmental Protection Committee (EPC) meetings (number and manhours)
6. Environmental Impact Analysis Process documents prepared and processed (number and manhours)
7. Fines and penalties paid (dollar amount)
8. Air pollution sources in compliance (number)
9. Air quality violations resolved (number)
10. Water pollution sources in compliance (number)
11. Water quality violations resolved (number)
12. Solid/hazardous waste facilities in compliance (number)
13. Solid/hazardous waste violations resolved (number)
14. Environmental permits in compliance (number)
15. Oil and hazardous substances spills (number)
16. Natural resources plans/agreements updated (number)
17. Other noncompliance conditions (number)

TABLE 5.4

Input/Output Measures Excluded

A. Measure: Amount of personnel training and education (input 2)
Reason: It is difficult to express amount of training and education in quantifiable terms.

B. Measure: Overhead and miscellaneous costs (input 6)
Reason: The EPF has minimal expenses in this category and records are typically not well kept.

C. Measure: Environmental training sessions conducted (outputs 7 and 8)
Reason: There is great diversity among bases in which organizations provide training for environmental issues, especially for spill response and hazardous waste management.

D. Measure: Destruction of resources due to pollution incidents (output 9)
Reason: Except for situations involving wildlife (e.g., fish kills), human lives, or facilities, data on damage is not normally estimated or maintained. Also, it is difficult to estimate damage in many instances, e.g., oil spills around the flight line.

E. Measure: Effective base population (output 11)
Reason: Not that meaningful compared to other measures when considering impacts on the environmental protection effort.

F. Measure: Number of reporting and record keeping discrepancies (output 21)
Reason: Most bases do not maintain data on this specific type of problem.

G. Measure: Past disposal sites with investigative studies completed (input 14) and Past disposal sites in site characterization or remediation phases (output 24)
Reason: The transition from investigative studies (Phase I) to further investigations and actual remediation in Phases II, III, and IV is not well established; many variables affect program progress after Phase I.

TABLE 5.4 continued

H. Measure: Land available for grazing and cropland management (input 16), forest management (input 17), and fish/wildlife/outdoor recreation (input 18) and receipts from grazing and cropland management (output 26), forest management (output 27), and fish/wildlife/outdoor recreation (output 28)

Reason: Relating available acres to receipts is difficult because so many variables affect the land's productivity (e.g., amount of land suitable for designated purpose and variations in local weather and market conditions).

Data Collection

A survey form was developed to collect data on all the selected input and output measures. The Air Force Engineering and Services Center distributed the survey by cover letter to eight Major Commands on 13 May 1986. (See Appendix E for the cover letter and survey form.) A Fiscal Year 1985 data base was used since this was the most recent reporting cycle and data could be more easily estimated for a recent year. The bases which responded are listed at Table 5.5. Surveys returned to the Center were forwarded to AFIT where the data was screened, manipulated, and loaded on the IBM-AT.

Screening. The first step in preparing the survey information for entry into the data base was screening for obvious errors. Several base environmental coordinators were called to either confirm the data or ask for additional

TABLE 5.5

Installations Returning Surveys

Altus AFB	Andrews AFB	Bergstrom AFB
Cannon AFB	Carswell AFB*	Chanute AFB
Charleston AFB	Columbus AFB	Davis-Monthan AFB
Dover AFB	Edwards AFB*	Eielson AFB*
Ellsworth AFB*	Elmendorf AFB*	England AFB
Hanscom AFB*	Hill AFB	Holloman AFB
Hurlburt Field	Kelly AFB	K I Sawyer AFB*
Langley AFB	Laughlin AFB	Little Rock AFB
Loring AFB*	Lowry AFB*	Luke AFB
MacDill AFB	Mather AFB	McClellan AFB
McChord AFB	McGuire AFB	Moody AFB*
Mt. Home AFB	Nellis AFB	Newark AFS
Norton AFB	Patrick AFB*	Reese AFB
Robins AFB	Seymour Johnson AFB	Tinker AFB
Tyndall AFB	Whiteman AFB*	Wright-Patt AFB
Wurtsmith AFB*		

* Not received in time to include in data analysis

information. Some of the data errors included: a) entering the wages as dollars per hour instead of yearly totals, b) entering an unreasonable number, such as a base generating only one kilogram of hazardous waste, and c) not showing proper correspondence between data elements, such as a base having air permit violations but listing no air quality permits.

While several of the elements called for estimated quantities, one element was suspect even for an estimate. The contracted services expenditure (I5) element ranged from $7,600,000 to $0. Discussions with several environmental coordinators revealed that there was variability in what respondents included in the element. Part of the problem resulted from misunderstanding the question or from interpreting differently the meaning of service contracting. Because of the suspected poor reliability, the variable was restricted to certain analysis runs.

Except for the obvious errors, all data was considered correct as noted in the assumptions in Chapter I. More discussion about the data will be in Chapter VII.

Manipulation. There were a total of 26 input and 24 output survey elements which potentially could be used as variables in the analysis. The survey was developed so that the elements could be used individually or combined appropriately to represent DMU measures. For example, depending on the purpose of an analysis run, the number of civilian and military manhours could be analyzed as two separate variables or as one combined variable without hurting measurement validity (i.e., the variable measures what it is expected to). Air, water, and solid waste violations are examples of output variables which can be analyzed separately as individual violations or combined as total base violations. Table 5.6 lists combined data base variables and their respective elements from the survey.

Some variables were entered as reciprocal values to place them in proper relationship to other input or output values. When the models attempt to optimize a DMU's efficiency, relatively low values for inputs and high values

TABLE 5.6

Combined Variables

Variables (and measures)	Survey Element (and Number)
Total Cost (I1,4,5)	Civilian Pay (10) Military Pay (11) Supplies Costs (12) Equipment Costs (13) Contracted Services (14)
Total Pay (I1)	Civilian Pay (10) Military Pay (11)
Supply and Equipment (I4)	Supply Costs (12) Equipment Costs (13)
Pollution Sources (I6,8,10,11)	Air Pollution (23) Water Pollution (24) Hazardous Waste (25) Solid Waste (26)
Violations Received (I7,9,12)	Air Quality (44 & 45) Water Quality (48 & 49) Solid/Hazardous Waste (52 & 53)
Compliance Status (O8,10,12,14,17)	Air Quality (47) Water Quality (51) Solid/Hazardous Waste (55) Environmental Permits (56) Other Conditions (59)

for outputs result in DMUs being rated more efficient. The measures that are devised so that high input and low output values are considered relatively good need to be expressed as reciprocals. For example, number of spills is an output which should be relatively low to improve DMU efficiency.

Reciprocal values of spills show DMUs with fewer spills as having a higher numeric value for that output measure, which is the desired relationship. Reciprocal variables include Pollution Sources, Hazardous Waste Generated, and Oil/Hazardous Substances Spills.

The computer program will accept zero values for outputs but not as inputs. Substitute values were created where the equivalent of zero was needed. In some cases, the maximum allowed value of 999,999 was entered so that the model would assign a very low weight to the variable, in a sense ignoring it. Since division by zero is prohibited, a value of two was used in place of the reciprocal of zero. This compares to a value of one which equals a reciprocal one; a value of two which equals a reciprocal one-half, etc.

Loading. Operating on the IBM-AT, Productivity Assessment Support System allows interactive entry of data using menus to direct user actions. Codes for each Major Command and base and names for each variable were devised, then used as key names in the data base. Once the codes and key names were entered, the menu asked for values of each variable. The data base was corrected using either the software menu or the system (dBase) file editor.

VI. Analysis and Results

This Chapter will review the computer program execution and discuss the test runs, including any problems encountered. The resulting reports will be analyzed keeping in mind investigative questions 2 and 3--are the analytical models and DMU measures appropriate? The analysis also has implications for investigative question 4 which addresses the application of these models. Further discussions concern investigative questions 5 and 6.

DEA/CFA Computer Program Execution

The interactive Productivity Assessment Support System program allowed many combinations of variables to be used for each analysis run. Variables for all or part of the observations (installations) can be compared as long as no more than 20 variables are used and the observation/variable ratio is at least two to one. To run the program the operator need only to specify the variables and observations for the DMU. Once the computer program has executed, various efficiency analysis results can be reported. Four reports used for this research and their descriptions are listed below (8:26):

1. Efficiency Report - for each DMU, provides input and output levels, adjusted variable levels, relative contributions, and shortages/excesses if any.

2. Comparison of Multiple Efficiency Analyses - provides a summary table showing CFA and DEA efficiencies and the average value for each analysis. Printouts of this report for each test are at Appendix F.

3. List Local Frontier Units - identifies the frontier units and their characteristics for each inefficient unit.

4. Summary of Local Frontiers - produces a listing of frontier organizations for each complete and incomplete local frontier.

When there was an option, CFA efficiencies were requested for all reports to ensure consistency in comparisons of DMUs. For Efficiency Reports, an evaluation of efficient outputs for observed input levels was specified. Analysis focused on outputs since more control generally is exercised over outputs than inputs. For example, bases usually have little control over their budgeted amount of funds and the number of pollution sources they have.

Initial Analysis Attempts

The first set of analyses was devised using combinations of variables to test efficiency in three areas. Table 6.1 lists the variable combinations for the initial analyses. The "overall" test included most of the measures (individually or in combination) representative of the entire EPF function. The "process" test included measures which consisted of administrative resources inputs and office generated outputs. The "results" test compared variables which reflected environmental compliance aspects of the EPF program. By comparing pollution sources (inputs) to violations (outputs), this test serves to evaluate effectiveness, rather that efficiency, in meeting compliance standards.

TABLE 6.1

Initial Input/Output Combinations

Inputs	Outputs
Test 1 - Overall	
Total Cost (I1,4)	Documents Reviewed (O1)
Manhours (I2)	Reports Prepared (O2)
Pollution Sources (I6,8,10,11)	Compliance Inspections (O3)
Hazardous Waste Generated (I13)	Incident Responses (O4)
Required Permits (I14)	EPC Activity (O5)
Natural Resources Plans (I15)	Environmental Documentation (O6)
Violations Received (I7,9,12)	Violations Resolved (O9,11,13)
	Compliance (O8,10,12,14,17)
	Oil Spills (O15)
	Natural Resources Plans Updated (O16)
Test 2 - Process	
Total Cost (I1,4)	Documents Reviewed (O1)
Manhours (I2)	Reports Prepared (O2)
	Compliance Inspections (O3)
	Incident Responses (O4)
	EPC Activity (O5)
	Environmental Documentation (O6)
Test 3 - Results	
Pollution Sources(I6,8,10,11)	Violations Resolved (O9,11,13)
Hazardous Waste Generated (I13)	Compliance (O8,10,12,14,17)
Required Permits (I14)	Permits Noncompliance (O14)
Violations Received (I7,9,12)	Oil Spills (O15)

The overall test for 17 variables was attempted using 34 observations which had been received by 24 July 1986. The DEA and CFA optimizations rated all DMUs as efficient, that is, having values of 1.0. Even though the run had twice as many observations (34) as variables (17), the models were not able to make meaningful comparisons. The diversity of variables and their values makes comparison difficult at this ratio of observations to variables. In trying to compare numerous attributes, the models give each DMU a high efficiency rating for at least one attribute.

Test 2 - Process was not run because of the previously discussed problem of too many variables. With fewer variables involved, Test 3 - Results was attempted using only 34 observations. The optimization identified 27 DMUs as efficient with values of 1.0, while ranking seven DMUs as less efficient. While more differentiating, this comparison also was not adequate for a realistic evaluation of installation operations. Even with these shortcomings, Test 3 - Results will be used as an example of how DMUs can be compared.

Appendix F contains the summary listings of DMU efficiency ratings provided by DEA and CFA. The upper bound columns are the DEA ratings and the lower bound are CFA. If DEA can envelop the input and output variables, then CFA analysis is not necessary and both upper and lower bound values are identical. If CFA is not able to complete envelopment, then both values are also the same. For Test 3 - Results, most DMU values are the same for these reasons. But DMU 10 is an example of a DMU for which CFA could envelop the variables after DEA could not. As explained in Chapter IV, the envelopment results in lower values for the CFA rating.

TABLE 6.2

Results of Test 3

DMU	Rating	Output Variable(s)
10	.2630	Violations Resolved, Compliance, Permits Noncompliance
14	.6667	Violations Resolved, Compliance, Spills
18	.3282	Violations Resolved, Compliance, Spills
21	.8000	Violations Resolved, Permits Noncompliance
57	.7835	Permits Noncompliance
63	.8856	Violations Resolved, Spills, Permit Noncompliance

Table 6.2 shows the seven inefficient DMUs giving the associated ratings and the output variable(s) which largely contributed to the inefficiency. The output variables were those identified in the analysis as having low "percent contribution to efficiency." The model identifies the percent contribution for each variable so that the variables

with the highest percent contribution is the most significant for the DMU. Percent contribution, which represents the weighting assigned to each variable for a DMU. As explained before, the weight assigned to each variable is assigned by the model depending on how a DMU is using resources compared to other DMUs. DMUs may emphasize a certain variable or combination of variables, so the significance of a variable should only be determined for the DMU being evaluated.

A good way to illustrate this is to compare two DMUs with similar efficiencies as shown in Table 6.3.

TABLE 6.3

Comparison of Variable Percent Contribution

Output	Contribution to Efficiency	
	DMU 3	DMU 50
Violations Resolved (O9,11,13)	39.818	39.785
Compliance (O8,10,12,14,17)	21.200	00.000
Oil Spills (O15)	38.906	60.216
Permits Noncompliance (O14)	00.000	00.000
	------	------
	99.924	100.001

By having successful efforts in the first three outputs, DMU 3 was considered as efficient as DMU 50 which was efficient in violations resolved and preventing oil spills. DMU 3 may want to emphasize performance in the last output to slightly improve its efficiency rating if the improvement can be done without excessive use of resources. Even though relative efficiency would not go up, DMU 50 could work to improve its low outputs.

A noteworthy characteristic of the Results test was that 19 of 34 observations had efficiency ratings of 1.0 due to the contribution of just one variable. As discussed before, this poor differentiation resulted from the models finding most of the DMUs efficient in at least one variable in relation to other DMUs. Because the observations did not more than double the number of variables, many DMUs had characteristics in which they could excel and thus be rated efficient. One method to alleviate the poor differentiation is to increase the observations by including more DMUs or by examining several DMUs over many time periods.

The Results test points out other interesting aspects of the analysis for EPFs. DMU 57 had only one variable (Permits Noncompliance) causing inefficiency, while the other DMUs had more than one. The value level for Permits Noncompliance was 0.0 which represents total compliance. Having a low output level for good performance seems illogical, but the justification relates to a comparison between inputs and outputs. In this case, the DMU had no required permits, which is given an input value of 999,999, representing relatively unimportant inputs. Therefore, neither input nor output for Permit Noncompliance contributed to the efficiency of DMU 57. Similar logic applies to other situations. For example, a DMU with five permits but with only four in compliance would have an input/output ratio of 4/5. A unit with a totally efficient variable would have five out of five permits in compliance for a ratio of one. Comparing one input to one output is only part of the models evaluation, since overall DMU efficiency is computed using comparisons of many variables and DMUs.

Examining DMU 57 and G, rated 78.322 and 88.600 respectively, shows how the models handle variables with zero input and output. Both DMUs had 0.0 or low values for two or three output variables, indicating they had few sources in compliance. However, their input levels of zero indicate they had few, if any, sources which have to be in compliance. Thus, while the DMUs were effective at avoiding compliance problems, they were rated as not being efficient in doing so. When evaluating the analysis results and making recommended changes, managers should consider that low efficiency ratings may not mean poor EPF compliance.

Once the inefficient variables or DMUs have been identified, the models determine how much change is needed to reach maximum efficiency. In the Efficiency Report, the models provide an adjusted input/output level which would bring inefficient DMUs up to a 1.0 rating. These levels are determined by multiplying the variables' values by a "multiplier for adjusting output levels." Managers could improve efficiency by attempting to reach these values without also raising resource consumption. For example, DMU 10 would need to improve compliance or reduce the number of spills as shown below.

Variable	Output Level	Multiplier	Adjusted Output
Compliance	167.0	3.8023	634.981
Oil Spills	5.0	"	19.011

In practical terms, DMU 10 would need to reduce spills from two to zero or noncompliance situations from six to two or less.

Analysis Results Using Variable Combinations

Considering the poor success of running analyses using only 34 observations, the analysis shifted to tests using fewer variables. Groupings of fewer than nine variables were devised to provide results which better evaluate EPF operations and the capabilities of the models to evaluate EPFs. Attempts to place variables into input or output combinations which have similar attributes, such as costs, manhours, or compliance issues were made. The new combinations are listed in Table 6.4.

One result of these analyses was immediately obvious. The reduced number of variables, and possibly the grouping of more comparable variables, resulted in better envelopment of DMUs and fewer efficient DMUs. EPFs could be better evaluated because of better DMU differentiation. Further detailed evaluations are in the following sections.

TABLE 6.4

Alternative Variable Combinations

Inputs	Outputs
Manhours 1	
Manhours	Documents Reviewed Reports Prepared Compliance Inspections Responses EPC Activity Environmental Document
Manhours 2	
Manhours Personnel Assigned	Documents Reviewed Reports Prepared Compliance Inspections Responses EPC Activity Environmental Document
Costs 1	
Total Pay Supply and Equipment Contract Costs	Documents Reviewed Reports Prepared Compliance Inspections Responses EPC Activity Environmental Document

TABLE 6.4 Continued

Costs 2	
Total Pay	Violations Resolved
Supply and Equipment	Compliance
Contract Costs	Oil Spills
Costs 3	
Total Cost	Documents Reviewed
	Reports Prepared
	Compliance Inspections
	Responses
	EPC Activity
	Environmental Document.
Costs 4	
Total Cost	Violations Resolved
	Compliance
	Oil Spills
Air Quality	
Air Sources	Air Noncompliance
Air Violations	Violations Resolved
Water Quality	
Water Source	Water Noncompliance
Water Violations	Violations Resolved
Solid Waste	
Solid Waste Facilities	Solid Waste Noncomp.
Hazardous Waste Generated	Oil Spills
Solid Waste Violations	Violations Resolved
Violations	
Violations Received	Violations resolved
Compliance	
Pollution Sources	Compliance
Required Permits	Permit Noncompliance

Manhours 1. Manhours 1 determined how efficient DMUs were in completing process objectives in relation to manhours, a key resource in the mostly white-collar EPF. DEA/CFA evaluated five DMUs as efficient (1.0), while the lowest unit was DMU 22 with .0380. A comparison of these extremes shows DMU 10 completed 909 units of output with 1859 manhours, while DMU 22 completed only 61 units of output with 13,566 manhours. Managers should keep in mind that only efficiency in using manhours is being evaluated and DMU 22 output may have been concentrated in some other area such as compliance. DMU 10, 8, 18, 21, and 66 had ratings of 1.0 and only one or two variables contributed to the efficiency. For example, DMU 21 had 16 EPC meetings which contributed 100 percent of the efficiency. Other variables (such as Inspections) had high values but were not needed to contribute to DMU efficiency. The same number of EPC meetings (16) was not enough to rank DMU 23 higher than 41.357 percent efficient since values of its input variables were higher. Surprisingly, the number of EPC meetings for DMU 1 was only the minimum number (four per year) required by Air Force regulations, yet it received 12.165 percent contribution to efficiency.

Conversely, not one DMU had all output variables contributing to efficiency. Disparities in contribution may result from the differences in variable characteristics and values, so that some variables continue to dominate efficiency. These results from Manhours 1 show how the models perform complex comparisons no manager could perform manually.

The results show that some DMUs dominate in certain areas. The Reports Prepared variable had zero contribution to efficiency in 22 of 34 DMUS. Apparently, a relatively high value of 1200 for DMU I resulted in other DMUs receiving low ratings for that variable. Even that high value only placed DMU I's efficiency at .525 percent. Managers may want to consider dropping extreme variable values to see how DMUs compare to units with more similar magnitude.

Manhours 2. Manhours 2 test added the input variable, Personnel Assigned, keeping output variables unchanged. Except for four ratings which essentially remained constant, all ratings went higher or could go no higher than their existing rating of 1.0. The addition of a variable may have given more areas for DMUs to excel and be efficient as discussed under the Results test. Of the four DMUs which changed little, DMU 20 remained identical because the Personnel Assigned variable contributed zero to input efficiency. Apparently the personnel assigned related to the other DMUs such that the other variables kept their same relationships. The similar alignment of ratings for Manhours 1 and Manhours 2 analyses was expected since the number of personnel (the new variable) is closely related to manhours.

Costs 1. Costs 1 tested DMU efficiency in using their financial resources as input to produce administrative output (e.g., paperwork). The models identified 12 DMUs as efficient. Once again, the efficient units received all of their rating from one variable. Managers need to be wary since slips in this variable could hurt the entire rating. The variations of DMU from Manhours tests to Costs 1 tests was dramatic except for some of the units rated as efficient. Of the six DMUs which remained efficient, four had one or two variables which contributed most of the efficiency in both tests. Regardless of this point, the six DMUs appear to have a good efficient combination of process output variables.

Costs 2. The Costs 2 approach was more results oriented to see how efficient DMUs were in using money to stay in compliance. Many of the efficient DMUs were efficient under Costs 1 and 2. Since the output variables changed, the efficient DMUs appeared to rely on the input variables to remain efficient. This test was the first analysis where all output variables contributed in some way to DMU efficiency. The reduced number (6) of variables or the variable characteristics may have caused more even distribution of efficiency contribution.

Costs 3. A noticeable difference occurred under Costs 3 where Total Cost was the only input variable. (Total Cost combines the Total Pay and Supply/Equipment Cost variables, but drops the Contract Costs variable.) Only three DMUs remained efficient (a drop from 11) and all but two DMUs dropped in efficiency. These lower ratings probably more accurately reflect the true DMU efficiencies. As mentioned in Chapter IV, Contract Costs had extreme variations in values which may have disrupted the evaluation. For example under Costs 1, Contract Costs contributed 52 percent of DMU 50's input efficiency by being a relatively low value. DMU 50 was rated 76 percent efficient under Costs 1, but with Contract Costs removed under Costs 3, the DMU was only 12 percent efficient. The high values for just a few DMUs may have made the remaining low values look much better and distorted their efficiency. Most other DMUs with dramatic drops in efficiency exhibited this same change.

The two DMUs that exhibited negligible change point out an interesting aspect of the analysis. The variables Supply/Equipment and Contract Costs were zero values (entered as 999999). The model ignored these two variables (giving them zero contribution) and used only total pay for comparison. In these cases, Total Pay was the same value as Total Cost for the Costs 1 test.

Costs 4. Costs 4 compared Total Cost to compliance variables and showed a familiar pattern of the DMU efficiency ratings dropping from the Costs 2 test. Only DMU 18 with a perfect compliance record and DMU 61 with 35 violations resolved were able to rate 1.0.

Table 6.5 ranks the DMUs in the two Manhours and four Costs tests according to their efficiency ratings. A correlation between DMU rankings in Manpower and Costs tests might be expected since total pay (Costs) is linked to manhours and personnel assigned (Manhours). Contracting Costs, which show a high degree of variability among DMUs, probably account for much of the efficiency differences. Correlation analyses tend to corroborate this idea. The correlation between DMU rankings in Manhours 1 and Costs 1 (includes Contract Cost) was only r = 0.380. The correlation for Manhours 1 and Costs 3 (excludes Contract Cost) was r = 0.837, which is considered over 99 percent significant for 34 samples. Combining Manhours 1 and Costs 3 into one test because of their similarities could produce as good or better results with less redundancy.

Compliance Tests

This section discusses analyses of variables which are results oriented and indicators of environmental compliance.

Air Quality. The most obvious result of this test was that most of the units were rated efficient (1.0) or inefficient (0.0). A zero efficiency rating is unusual for DEA and CFA, but is understandable considering the way the tests were set up. Efficient units had output equal to input--they were in compliance and resolved all violations. The ineffecient units had zero inputs and outputs--they had not air pollution sources or violations. Basically, the

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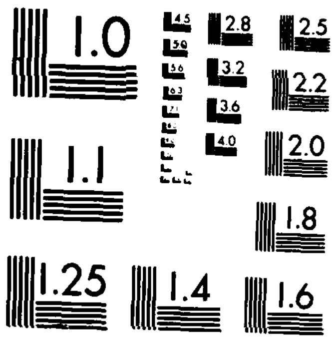
PROGRAM PERFORMANCE(U) AIR FORCE INST OF TECH
WRIGHT-PATTERSON AFB OH SCHOOL OF SYSTEMS AND LOGISTICS
UNCLASSIFIED   S W COYLE SEP 86 AFIT/GEM/LSM/86S-7   F/G 5/1   NL



MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

TABLE 6.5

DMU Rankings for Manhours and Costs Tests

DMU	Man1	Man2	Cost1	Cost2	Cost3	Cost4
1	2	1	14	1	9	3
2	9	6	12	2	15	9
3	21	22	7	1	22	8
6	18	5	20	4	11	4
8	1	1	1	13	7	13
10	1	1	1	1	1	11
12	23	25	1	9	30	27
14	25	27	16	10	16	23
16	7	7	15	14	18	26
18	1	1	3	1	2	1
19	12	2	13	17	3	27
20	5	9	7	15	8	15
21	1	1	1	1	1	6
22	2[illegible]	28	22	12	31	25
23	8	10	18	6	12	18
50	27	24	4	1	27	16
51	26	23	19	11	26	24
53	13	12	1	1	13	7
54	3	4	1	5	4	5
55	10	11	11	1	10	12
56	15	21	17	19	24	26
57	11	15	10	8	25	14
58	16	16	1	1	19	1
61	20	20	21	16	29	19
63	14	14	1	7	21	20
64	24	26	8	22	25	17
66	1	1	1	1	1	2
70	17	13	9	18	20	28
71	14	8	1	1	14	21
72	16	18	6	23	28	31
73	4	3	1	1	5	10
74	22	17	5	20	23	29
75	6	1	1	21	6	30
76	19	19	2	3	17	22

inefficient ratings should be ignored since the DMUs did not need to be in the comparison anyway. Including DMUs with zero values may have distorted the results by making zero the baseline input and output comparison value for other units.

Water Quality. This test had characteristics similar to Air Quality.

Solid Waste Quality. The Solid Waste test showed more differentiation than the Air and Water tests probably because of the additional input and output variables, Hazardous Waste Generated and Oil Spills. These variables appeared to have other effects. Evaluating solid waste compliance performance in relation to the amount of hazardous waste generated placed many larger or industrial installations at close to 1.0 efficiency ratings. In comparison, one Solid Waste Quality test run without the Hazardous Waste Generated variable rated the large DMUs consistently lower. These large units' compliance was relatively not as good but their compliance problems were greater.

Violations. This test determined how efficient DMUs were in resolving existing pollution violations. Eleven units were rated efficient (1.0) while eight DMUs were rated inefficient (0.0). In the case of inefficient units, the results must be carefully interpreted. For most of these units, the DMUs had no violations (zero input) and therefore nothing to resolve. The model ranked these as inefficient, but managers should disregard the DMUs' ratings for this test.

However, DMU 10 had one violation which was not resolved, resulting in an inefficient rating. A low rating would be expected and the manager should be able to recognize this relationship.

Compliance. The comparison for compliance resulted in much different results and greater DMU differentiation than violations because of the addition of one variable and the use of reciprocal values.

In an attempt to improve test runs by reducing the number of variables, the other extreme of too few variables was reached. In the cases of Air, Water, and Solid Waste, and Violations, the problem was accentuated by many zero value variables. The Violations test had only one input and one output, usually with single digit numbers. These efficiency ratings were predictable and the ratios easily calculated by hand. So for some tests, the models' capabilities were not adequately used. The compliance tests need to be combined to adequately differentiate among DMUs so that differences in efficiency are discernable. Of course, the number of observations for this research restricted the combination attempts.

Reducing the number of variables in the Compliance tests illustrated how frontiers are related to variables.

Efficient units form the efficiency frontier for inefficient units with similar mixes. They have similar input and output ratios (not magnitudes). Efficient frontier units determine the input and output weights for bringing other units up to efficiency (8:52).

Solid Waste Quality was one of the few tests in which "complete frontiers" were formed to totally envelop the inefficient DMUs. One of the three frontiers was composed of DMUs 20, 51, and G. To become efficient and reach the frontier, DMU 10 would need 0.33 more efficiency to reach DMU 20 or 51 and no more efficiency to reach DMU G.

Fisher observed that the number of variables affects the number of units reaching efficiency (23:94). Fewer variables used in the tests reduces the size of the efficiency frontier and thus the number of units which can reach the efficiency frontier. In looking at Table 6.6, this relationship held true for the some of the Process tests, but not for the Results tests. The disparity probably resulted from the problems with the test arrangements discussed before.

Use of the Reports

Investigative Question 4 asked about the use of DEA/CFA results by EPF managers. Productivity Assessment Support System generates numerous reports, three of which were used in this Chapter. Managers can use these reports

TABLE 6.6

Comparison of Variables to Efficiency

Test	Number of Variables	Ratio of DMUs to Variables	Number Efficient	Percent Efficient
Costs 1	9	3.78	12	35
Manhours 2	8	4.25	7	21
Manhours 1	7	4.86	5	15
Water	4	8.50	14	41
Violations	2	17.00	11	32

to evaluate the efficiency (e.g., manhours and costs) and effectiveness (e.g., violations and compliance) of their DMUs and find inefficient areas. But managers are responsible for correctly interpreting the results, keeping in mind what different variable combinations can do to the test. Each test must be interpreted separately, then in relationship to other tests, before taking management actions.

The reports provide "adjusted output levels" that managers should strive to meet to make DMUs more efficient. The higher the percent contribution, the more significance the model is putting on a variable. Managers should strive to improve variables with lower percentages since they are contributing the least to efficiency. For environmental compliance, the manager would need to ensure that attempts to improve efficiency did not result in lowering effective-ess. For example, producing more reports may improve efficiency but may have increased noncompliance as a concomitant outcome.

Productivity Assessment Support System reports provide listings of frontier units which are used as comparison for other less efficient DMUs. The DMUs and the comparison frontier units have similar mixes of input and output values. Managers can study the efficient units to make changes in their DMUs, modeling operations after the efficient units. Once again, managers would need to be careful not to overemphasize some measures at the expense of others which could result in serious violations. Also, managers may feel that high efficiency contributed by a few measures is not a desirable situation. More emphasis may need to be placed on the other variables to have a better balanced program.

Managers do not have to be passive in conducting analyses. Following the methodology in this research, they can determine the number and types of variables in a particular analysis. As was seen earlier, comparisons of similar measures provide different results from dissimilar measures. Also, the number of variables affects the number of efficient units identified. Fewer variables usually results in fewer units reaching the efficiency frontier.

Another step managers can take is to assign weights to the variables rather than allowing the models to determine them. Air Force managers assigned weights for Donovan's research (22) with positive results.

Finally, managers can operate Option 4, Explore Alternatives, of the Productivity Assessment Support System which provides "what if" capabilities. By manipulating particular variables, managers can see the overall effect on DMU efficiency. The information allows managers to evaluate tradeoffs between inputs and outputs prior to actually making changes. Managers must interpret the results for their DMUs taking into consideration unique characteristics.

Headquarters Air Force and Major Commands would have use for these analyses from different perspectives. Major Commands may want to compare base programs to see if there are inefficient units or if there are efficient units which can serve as models. One important evaluation would be to ensure that base DMUs place proper operational emphasis on results measures. Headquarters Air Force would be less interested in individual base performance than in agency ability to reach overall program success. Air Staff could run the model using the data available from the Defense Environmental Status Report as was the case in this research for some of the Results tests. Their evaluation would find poor performance areas, possibly indicating needed program changes.

Implementation of the Models

Investigative question 5 pursues the idea of how analytical models can be implemented in the Air Force to allow managers to study EPF performance. The models of choice are DEA and CFA which must be computerized to be useful to the manager. Running these models with several variables for several observations must rely on computer computational power. Even the IBM-AT microcomputer's slow processing time would be too time consuming for managers. A minicomputer or remote hookup to a computer mainframe would be necessary for practical office application.

Each manager would require access to a computer terminal since these programs work best interactively. Using their experience with a particular installation, managers would want to be able to alter the list of measures and possibly assign weights to them. The models need to be run regularly to observe trends in performance, and "what if?" analyses require direct terminal interface. Depending on the operating system and data base used, data could be entered for the measures and the model run nearly on a real time basis. This research required too much data manipu-ation to allow realistic application to the office environ-ent. Either operating system features or program software changes could be made to automate the data manipulation steps. In this way, managers could enter data directly from the reports or surveys.

Improvements to the Productivity Assessment Support System software would benefit practical use of the models. While the System is touted as being user friendly, the author encountered numerous obstacles to free interaction. After going several levels into the program menu to perform an operation, the operator must return to the upper level to change an item to be evaluated. The edit function for changing variables was tedious, requiring a complete hierarchy of identification for each variable to be entered for each change. Some errors in processing occurred: a) The program often could not handle values that overflowed field length, causing termination rather than an error statement and continuation of processing; b) The edit function often found the wrong variable from that which was requested; and c) Some subroutines would not find the correct variables when an identification number above 10 was used.

All Air Force units should be aware of the models' current limitation of 20 variables and the two to one observations to measures ratio. Air Staff would have numerous bases available for comparison, but Major Commands and installations may need a series of comparisons. Evaluations over several time periods, as done by Donovan (22), would increase the number of observations and provide other benefits, such as indicating performance trends.

Implications for Operational Changes

This section addresses investigative question 6 to determine if the analysis results in any suggestions for operational use or improvement. The data analyses performed indicate that some installations are more efficient at using resources, some are more effective at being in compliance and some perform well in both categories. By comparing DMU rankings in these categories, some indication of installation performance necessary for compliance may be indicated. Table 6.7 lists the 34 DMUs and their average rankings in the various tests performed.

TABLE 6.7

DMU Rankings for Process and Compliance Tests

DMU	Process Rank	Compliance Rank	DMU	Process Rank	Compliance Rank
1	7	12	2	10	22
3	19	5	6	14	14
8	8	15	10	4	27
12	25	13	14	27	17
16	22	18	18	2	30
19	17	28	20	13	10
21	3	24	22	31	6
23	16	1	50	23	7
51	30	9	53	9	19
54	5	26	55	12	21
56	28	16	57	21	29
58	11	3	61	29	25
63	18	12	64	28	11
66	1	8	70	24	23
71	13	15	72	28	20
73	6	2	74	26	23
75	15	4	76	20	18

The average DMU ranking for Process tests was compared to the ranking for Compliance tests using correlation analysis. With r = -0.097 between the Process and Compliance rankings, there are few implications of how organizations' efficiency can help their compliance effectiveness. The lack of correlation may indicate that DMUs with compliance problems are concentrating on processing violations rather than paperwork. Some of the DMUs with high or low rankings had the following characteristics:

DMU 18 - High efficiency, low compliance. It had very few compliance problems or pollution sources, so its efforts were apparently focused on administrative matters.

DMU 22 - Low efficiency, high compliance. The compliance record resulted from a larger number of sources which were in mostly in compliance. Very few documents were produced.

DMU 23 - Medium efficiency, highest compliance. A large number of sources were in compliance. But a large staff to stay in compliance apparently reduced efficiency.

DMU 57 - Low efficiency, low compliance. The unit had few sources or violations, but had high costs. The high Contract Costs may have indicated it was working on other compliance efforts, such as the Installation Restoration Program, not evaluated by this research.

DMU 61 - Low efficiency, low compliance. The low marks apparently came from few reports produced and a large number of noncompliances.

DMU 66 - Highest efficiency, high effectiveness. This model unit had very low costs and manhours, but attained good compliance for many sources.

DMU 73 - Similar characteristics to DMU 66.

These assessments are not totally valid characterizations of the actual organizational performance. But using analysis techniques similar to the ones presented in this research, the Air Force could use efficient and effective DMUs as models for other units.

Concentrating on increasing outputs is one of the few ways EPFs can expect to increase efficiency or effectiveness. Unfortunately, "more for less" does not set well with EPFs, since they cannot be expected to keep up with skyrocketing environmental compliance requirements with existing resources. EPFs will probably not be getting more efficient as they are constantly trying to increase resources. The increased resources could result in more output helping to maintain efficiency and improve effectiveness levels. However, reducing inputs, such as sources of pollution, should not be slighted. Hazardous waste reduction is an excellent method to reduce costs and pollution potential.

VII. Conclusions and Recommendations

Introduction

This chapter presents conclusions about the development of Environmental Planning Function (EPF) measures and the use of these measures in the analysis model. Conclusions are made for each of the research objectives presented in Chapter I. Chapter VI discussed ideas about the use of the model by managers and its applications in the Air Force. This chapter makes recommendations about the feasibility of implementation, taking into account the limitations of the model and computer program. Additional recommendations relate to other findings made during the research.

Conclusions

The main objectives of this research were to develop measurement criteria for the EPF, find a model to evaluate these measures, and test the model for possible use at Air Force installations. Specific conclusions about the success in meeting the research objectives are discussed below.

Objective 1. The first objective was to determine the measures which define EPF operations. Chapter III described important aspects of public agency productivity and suggested possible environmental agency input and output measures. Chapter IV proposed a methodology for selecting measures, then Chapter V made the actual selection. The following are conclusions regarding Objective 1:

1. A detailed set of input and output measures for environmental agencies can be developed, even though public service organizations are difficult to characterize. More measures are usually needed for public agencies than for private firms (10:273; 25:385). Hence, the EPF was described in quantitative terms using 32 process or results oriented measures. Even so, the measures did not account for all of the Environmental and Contract Planning section and all programs, such as Installation Restoration. The measures developed during this research already need updating as program emphasis shifts from traditional areas (e.g., air and water pollution) to the Environmental Compliance and Management Program and other new programs. Developing measures is an iterative, dynamic process.

2. Few public or private sector organizations are available as prototypes for developing EPF measures. Chapter III reviewed literature on productivity measurement in various agencies, but few studies were found specifically on environmental agency measurement. The scant research was not surprising because of the past philosophy that environmental efforts were not part of mainstream, conventional programs. The lack of examples made output measure development especially difficult.

3. Some of the measures developed by the author and validated by Air Force experts are more meaningful than others. For example, Total Documents Reviewed (I1) and Total Reports Prepared (I2) have relatively less validity since organizations such as the EPF normally do not track them and variability in document type and length can be great. On the other hand, documenting and tracking some paperwork are important duties of environmental organization personnel. Environmental Impact Analysis Process documentation (O6) is a critical aspect of base work and personnel should be aware of this output. Managers may want to weight measures if they feel this type of disparity in the importance of measures exists.

4. Output measures are more difficult to develop than input measures. For example, the output measure, Responses to Environmental Incidents (O4), was intended to show how much the base EPF could respond with given resources. Conversely, a base with good training for personnel handling hazardous materials and good spill prevention plans should need to respond to incidents relatively less often. Responses (O4) may show EPF efficiency, but the measure may be in direct opposition to effectiveness measures, such as Oil Spills (O15) which measures effectiveness in preventing incidents. Evaluating efficiency (e.g., response) and effectiveness (e.g., spill prevention) separately is one way to avoid this problem

Objective 2. The second objective was to collect data on the measures established for the EPFs. Using a survey sent out by the Air Force Engineering and Services Center (AFESC) under Project IMAGE, data from CONUS installations was collected to use in testing the analysis model. The following are conclusions regarding Objective 2:

1. The surveys are rich in information about environmental planning. In addition to the data used for performance analysis, other information is available to evaluate program trends and regional differences.

2. Data collected for some of the survey elements showed extreme variations in values. As mentioned in previous chapters, measurement error probably occurred in some data elements, such as service contracts (I5). Other variations occurred because of differences in base programs or state and regional requirements. As pointed out by some respondents, some states require each air pollution source to be permitted separately, while other states allow all sources to be covered under just a few permits. Accounting for these variations during data collection would be difficult, but may be necessary to ensure proper EPF comparison.

Unfortunately much of the disparity and error may have been caused by shortcomings in record keeping practices. Some respondents had difficulty making estimates about environmental documentation data which could be requested at anytime by regulatory agencies or by individuals under the Freedom of Information Act. Other evidence of poor records was that the Number of Inspections (O3) often did not meet the minimum set by regulatory agencies for various types of pollution control facilities. These data base gaps tend to confirm Nash's contention (31:159), presented in Chapter 3, that performance information is seldom available in usable form. Even though EPF personnel could answer the surveys, they do not collect all of the data on a regular basis.

Objective 3. The third objective was to analyze the data using an analytical method considered appropriate for EPFs. Constrained Facet Analysis (CFA) was selected for its capability to evaluate multiple inputs and outputs of varying units of measure. CFA was also preferable to the similar Data Envelopment Analysis since it could evaluate outlier units with dissimilar mixes of inputs and outputs. According to the literature review, CFA has established credibility in some public agencies (primarily schools) and has been shown to have potential applicability in the Air Force. Even so, the author is not aware of any attempt by the Air Force to examine CFA capabilities in comprehensive studies, including actual field tests.

Objective 4. The intent of the fourth objective was to analyze the test results and evaluate the success of the selected measures and model. CFA was able to analyze the data and provide results which rated the efficiency of 34 EPFs. Most of the test runs were successful in differentiating the EPFs on the basis of either their efficiency in office work or effectiveness in compliance. Some test runs were unsuccessful because of model and measure characteristics discussed below.

1. Limitations of the Productivity Assessment Support System computer program and the CFA model restrict their practical use. Research by other Air Force Institute of Technology (AFIT) graduate students revealed similar shortcomings.

a. The computer program was somewhat "user unfriendly" and a few logic errors exist. Considering the amount of manipulation required, data entry would be troublesome for managers, probably requiring a technician. Furthermore, the microcomputer data processing and reporting operations were time-consuming (the author took over 60 hours during this phase). Finally, some of the reports are difficult to interpret without a working knowledge of CFA theory and operation.

b. CFA appeared to have difficulty handling extreme value ranges of variables. Byers and Waylett noticed that if the range was too large the linear programming matrix often failed to produce meaningful results (11:118). Variables with value ranges of 0 to

999,999 were being evaluated in some tests. The Test 1 - Overall analysis, which gave efficient ratings (1.0) to all 34 EPFs, may have been influenced by the wide range of variable values. Successful tests not only had fewer variables being compared, but had variables with similar value ranges.

c. Another limitation was that the model would not process zero input values, so they were entered as 999,999. For the Contract Service Costs (I5) variable, this meant that both $0.00 and $1,000,000.00 were entered as $999.999.00.

2. Late survey returns and difficulties in computer processing restricted the number of tests accomplished. During the various testing stages the need for additional testing became apparent.

a. For proper data representation, reciprocal values were only used for selected variables. Using reciprocals is a legitimate research technique, but has the limitation of not always maintaining linear relationships in the data which may have existed prior to conversion. The Compliance variable (O8,10,12,14,17) was a reciprocal value for the number of air, water, and solid waste compliance problems. These compliance problems were also used as individual output variables in nonreciprocal form. A comparison of these variables as X versus 1/X may have shed more light on the appropriateness of using reciprocal values.

b. A test run evaluating all organizational measures was never completed. The number of observations was not sufficient to run against the 17 variables in Test 1 - Overall. More observations could come from having more base responses or evaluating EPFs in longitudinal studies (i.e., over several time periods). Fisher and Kellog noted that measuring total unit productivity, not just component parts, was necessary to identify all inefficiencies within an organization (23:98; 29:142).

c. Because of the restriction on the number of variables, values for six manhours variables (O1,2,3,4,5,6) were not entered. Thus, manhours inputs (I2) were never compared to number of manhours output (O1,2,3,4,5,6). The results of comparing identical measurement units, manhours, would have given further insight into CFA's capabilities.

Objective 5. The final objective was to discuss the feasibility of CFA application given the analysis results. Chapter VI discussed in detail the potential CFA applications and implementation strategies. The main conclusion is that CFA appears to be useful for Air Staff, Major Command, and EPF managers to use in making resource allocation and program emphasis decisions. As Nash stated (31:174), just the act of measuring helps to clarify goals and assess priorities.

1. A comparison of EPF rankings for process and results tests showed no strong correlation between EPF efficiency and effectiveness. Of course, the poor

correlation does not disprove the proposition that a base will improve compliance as it increases efficiency. The lack of correlation is understandable considering EPFs frequently are forced to abandon efficient courses of action in order to react to a new onslaught of regulations.

2. Of more significance to managers is the potential of using either CFA reports or model bases to improve EPFs. CFA reports can indicate which measures are contributing poorly to EPF efficiency or effectiveness. Managers can plan operational changes and evaluate their effect using computer program subroutines which predict outcomes. Other planning assistance comes from examining efficient units and comparing them to inefficient EPFs or program areas. The frontier reports indicate which EPFs are similar in input and output mixes so the comparison is more significant.

3. Actual use of CFA tools by EPF managers would tend to be base specific. Since base environmental programs are interdisciplinary in nature and directed by Environmental Protection Committees, many EPFs tend to emphasize programs and approach compliance differently. And EPFs take different operational approaches to state/regional political and regulatory considerations which reduces the chances for a consistent pattern. Using similar techniques to manufacture or repair items, production oriented organizations tend to have more operational consistency from base to base.

Recommendations

This research indicates that EPFs can successfully be characterized in terms of input and output measures and analyzed using a quantitative model. The following recommendations are made with this in mind.

1. Continue to study performance factors of private and public environmental organizations. The continual growth in the organizational significance of environmental functions warrants academic institutions, such as AFIT, pursuing this research. A more in-depth review, possibly including primary data sources, may find research which can more directly contribute to the characterization of environmental organizations and their measures.

2. Re-evaluate the EPF measures and their variable counterparts, and re-validate that CFA is appropriate for EPFs. More of the EPF operations, such as the Installation Restoration Program, may need to be included. However, the evaluation should consider dropping the less important measures and consolidating other measures or variables.

3. Re-program the Productivity Assessment Support System so it is more user friendly and practical for managers. The users manual (8) should be expanded to include more information on the interpretation of results. Also, re-configure the program so that more than 20 variables can be evaluated at once (as allowed by CFA theory) and so there is more flexibility in choosing variable combinations.

4. Continue to collect and analyze data to further characterize the EPFs. Recommend that this survey information, and other data collected under Project IMAGE, be retained by the Engineering and Services Center so that more research can be attempted. For example, correlation studies on EPF performance in relation to location could show state or EPA Region trends. Ratios of personnel assigned to personnel authorized compared to efficiency or effectiveness could indicate effects of manning levels on EPF performance.

5. Measure Air Force EPF efficiency and effectiveness on a regular basis using a combination of qualitative and quantitative means. Quite similarly, Byers and Waylett advocated an "integrated automated management information system" (11:117). The Defense Environmental Status Report could serve as one qualitative evaluation method and CFA could serve as the quantitative technique. Proper measurement is important to demonstrate Air Force compliance and is critical to justify increases in funding and manpower. Project IMAGE efforts and CFA analyses (including AFIT theses) should be integrated with manpower studies to improve Air Force EPF resources.

6. As an adjunct to the previous suggestion, institute a better environmental record keeping system. The Work Information Management System (WIMS) appears to be an ideal system for accomplishing this. Headquarters Air Force

and Major Commands should develop criteria for the types of data to be collected and evaluated. HQ USAF/LEEV should strengthen Air Force accountability procedures for compliance data. HQ USAF/LEEV should also work with the WIMS monitor to improve methods for environmental analysis documentation under existing work tracking procedures. And separate record keeping categories for the environmental media (air, water, and solid waste) need major expansions to accommodate information for audit and analysis purposes.

7. Implement some performance evaluation model, preferrably CFA, Air Force wide. Most of the advantages and disadvantages of CFA have been well documented, so further study of the model for individual decision making units appears to be of marginal value. The next step should be a feasibility study to demonstrate CFA's capabilities in either Civil Engineering or total Air Force settings. HQ AFESC/DEM should take the lead for Civil Engineering in working with other Air Force functional areas in pursuing the idea. HQ USAF/LEEV should validate the need for the feasibility study and, if appropriate, provide support for acquiring CFA because of its importance in evaluating EPF performance.

The above recommendation is made with two reservations. The first is that the author feels CFA implementation could not be justified solely for EPF use. The second reservation is that implementation is attractive only if CFA can be placed on existing systems. The Air Force should acquire the rights to modify the computer software so that it can be placed on Air Force systems and adapted to our requirements. WIMS would be the ideal system for Civil Engineering, especially if the computer model could have direct access to an augmented environmental data base.

Appendix A: Review of Productivity Analysis Methods (15:53-62)

Regression

Ordinary least squares regressions of the single-output, multiple-input variety having both positive and negative error terms produce curves of average relationship. These curves do not represent frontiers, which by definition are based on extremal relations. Actual output values lie above and below the regression curve, and the outputs of efficient units are not necessarily greater than their corresponding regression estimates. With stochastic models, additional information is gained by decomposing residuals, but for frontier estimation in the type of problems which have been addressed by DEA, average estimates are uninformative. Furthermore, in some cases the size and direction of the residuals may appear to have little or no bearing on the efficiency measure (distance from the frontier).

A major difficulty arises in the multiple output case when least squares regression analysis is performed on each output separately. The other outputs excluded from the analysis have an implicit impact since they may rely on (compete for) the same resources. Each regression equation might be able to predict adequately an expected level of a single output for an organization, assuming this organization could experience any of the random fluctuations or inefficiencies of the industry (all firms) and recognizing that the influence of other outputs are implicitly taken into account by the deviations from the regression line (residuals). But these equations cannot predict the expected output of an organization whose variations and/or inefficiencies are significantly affected by the given technology and policies of the firm which are not random. Magnitudes of actual outputs of an organization are influenced by both local and corporate policy which may prevent the true expected output values of the organization from conforming to the corresponding regression estimates. Furthermore, there might be little or no correlation between the relative magnitude of actual organizational outputs and the relative magnitudes of their regression estimates, yet relative magnitudes have an important effect on the establishment of frontiers and neighborhoods of comparison in multiple output situations.

If a linear least squares regression equation, with all of its assumptions, is accepted as a proper representation of organizational productivity, then according to Sherman the "relationships estimated by regression techniques reflect (approximately) efficient input-output relationships." The rate of technical substitution of any two inputs--the ratio of the regression coefficients for those inputs--is assumed constant for all organizations. Moreover, the rate at which an input is transformed into an output is assumed to be the same for every organization.

Under these assumptions, the average output of an organization is not expected to increase unless one or more of the inputs increase; and, if any input is reduced, then another input must increase or the expected output will be reduced. These relationships are those that one would expect to find in organizations having efficient productive capability. In inefficient organizations, either the same output can be achieved with reduced inputs or greater output can be achieved with reduced inputs or greater output can be obtained with the same resources.

Perhaps Sherman used the term "approximately" in allowing for the random output variability represented by the regression residual. This variability is assumed to be caused by reasonable, efficient adjustments of output levels in response to random shocks in production or random market fluctuations. However, if organizations are operating under different technologies, the variances in outputs caused by differences in technical efficiency would be subsumed by this residual term. These variances are not random. Two organizations having precisely the same inputs but different levels of technical efficiency would also have two different expected output levels, and the difference would be accounted for in the residual term. Least squares would consider efficient and inefficient organizations simultaneously and the best fit would be influenced by both types of behavior, including the case where residuals are forced to lie below the frontier. Under such conditions, a single regression equation would misrepresent the productive capability and efficiency of the units.

One would expect that removal of the subsumed difference in technical efficiency from the residual term would produce a regression equation which explains more of the variation in output (higher R^2). Sherman tested this hypothesis with a simulation; and Bessent, Bessent and Clark were able to support his findings by using DEA to identify the efficient organizations in a sample (n=216), then applying least squares regressions to the efficient units only, and comparing these regression results with the ones obtained when all units were considered.

The R^2 value increased when only efficient units were used in the regression. There were also modest gains in the significance levels of regression coefficients. These improvements were achieved despite the reduction in residual degrees of freedom.

If there exist an adequate number of efficient units in the data set, the above results suggest that one should perform regression (linear or nonlinear) on only the efficient units to obtain the best regression equation, one which comes closer to representing a frontier and which explains a larger portion of output variability.

But, it appears at this point that current regression analysis techniques are largely inappropriate when establishing frontiers for nonprofit organizations which do not have highly mechanistic, scientifically engineered production technologies. DEA, on the other hand, provides a useful representation of an attainable production frontier, provides pertinent information about organizational efficiency, and is not subject to the errors and misrepresentations which can result if the regression assumptions are violated or if the from of the production function is misspecified.

Furthermore, DEA takes all outputs and inputs into account simultaneously including differences in input/output mixes and tradeoffs among factors. It indicates which organizations are on the efficiency frontier, establishes a piece-wise linear approximation of the frontier surface using efficient units, and assigns an efficiency measure based on how far the unit is from a frontier point directly between the unit and the origin, a point for which input and output values are linear combinations of the observations from an efficient set of "neighborhood" organizations. Evaluations of frontier points, neighborhoods, and efficiency measures for individual units are all readily accessible through DEA but are hidden from explicit examination in the regression analysis.

Although DEA appears to be the best alternative for analysis in the public sector, further research is needed to determine how the models of DEA and statistical econometrics can be used in conjunction with one another to improve frontier estimation and analysis. It is likely that a more thorough frontier analysis will be achieved by the use of a number of different but related models.

Ratio Analysis

Ratio Analysis is not a method of frontier estimation, but it is relevant to this discussion because of its frequent use as an ex post facto evaluation tool in analyzing multiple input, multiple output relations. Users of this method examine multiple measures in the form of ratios in an attempt to compare the performance of similar organizations; each ratio typically being a single output measure divided by a single input measure. Like DEA, ratio analysis is used when the production process in unknown or difficult to model.

Unlike DEA, ratio analyses do not make use of mathematical models to organize or assimilate ratios into a single aggregate measure of efficiency; i.e., they do not simultaneously take into account interactions over the full range of inputs and outputs. As a result, the performances of organizations are difficult to compare using this method particularly when organizations rank comparatively high on some measures and low on others.

This difficulty can be illustrated by the following simple example. Consider the two organizations in Table 2.1.

TABLE 2.1

Difficulties in Using Ratios to Compare Performance

	Organizational Units	
	A	B
Output	1	1
Input 1	1	2.5
Input 2	4	2.5
Ratio 1 (=Output/Input 1)	1	0.4
Ratio 2 (=Output/Input 2)	0.25	0.4

Note, Ratio 1 of organization A is larger than Ratio 1 of B, and the situation is reversed for Ratio 2. The relative performance of organizations A and B cannot be determined by examination of these ratios unless the relative importance (weight) of each ratio is specified. Furthermore, as the number of inputs and outputs increases, the problems of weighting and assimilation grow multiplicatively.

Lewin, Morey, and Cook examined this problem in an evaluation of judicial districts. They ranked each of ten output-to-input ratios (2 outputs x 5 inputs) and displayed the number of times that districts were ranked in the upper and lower quartiles over the ten ratio measures. Several districts were noted to have ratios in both quartiles. Under these circumstances, it would be very difficult to find a simple rule to distinguish efficient districts from inefficient ones without making subjective judgments about the relative importance of each ratio.

Another related difficulty stems from the fact that single ratios provide only partial, incomplete measures of multiple input-output relations, a condition which often leads to incorrect judgments of performance. In actual practice, partial measures such as "units produced per manhour" are used as measures of performance without regard to other inputs such as supplies, fuel, equipment, etc. The data in Table 1 can be used to illustrate the risk in this practice. If one were to compare units A and B based on Ratio 1 alone, unit B would appear to be a better performer than A ($0.4 > 0.25$), but the reverse would be true if Ratio 2 were considered alone.

Sherman and Bessent, Bessent and Clark used DEA as a vehicle for examining the risks of partial measurements. Each experiment used a set of hypothetical organizations whose inefficiencies were known and detectable by DEA. DEA efficiency evaluations were performed on the sets with all inputs and outputs included. Other evaluations were performed with one input or output omitted. The results indicated that partial measures can cause misclassifications of efficiency; i.e., organizations might be incorrectly labeled efficient or inefficient, or the magnitudes and causes of the inefficiencies might be misspecified. In general, the omission of relevant inputs or outputs during frontier evaluations may cause distorted neighborhoods of comparison, erroneous slack conditions or measurements relative to the wrong frontier facet.

Despite the above shortcomings, ratios do have the advantage of being familiar to managers and simple to understand. But this advantage is outweighed by the risk of obtaining misleading results unless ratio analysis is used in conjunction with methods of frontier estimation like DEA which are able to take all inputs and outputs into account simultaneously.

Appendix B: Environmental Quality Program Goals

1.1 - Clean Air Goals

Comply with the Clean Air Act by:

- o Identifying and correcting all air pollution deficiencies.
- o Obtaining required permits, variances, and compliance agreements.
- o Completing required transportation control plans.
- o Implementing vehicle inspection and maintenance (I&M) program where required.
- o Completing required air episode plans.

1.2 - Clean Water Goals

Comply with the Clean Water Act by:

- o Identifying and correcting all water pollution deficiencies.
- o Obtaining required permits and compliance agreements.
- o Using municipal or regional treatment facilities when economically feasible or required under approved plans.
- o Developing and implementing oil Spill Prevention, Control, and Countermeasures (SPCC) plans and programming required projects.
- o Eliminating oil and hazardous substance spills from installations and ships.

1.3 - Solid and Hazardous Waste Goals

Comply with the Resource Conservation and Recovery Act (RCRA), and the Toxic Substances Control Act (TSCA) by:

- o Complying with the regulations for handling, storage, transportation, and disposal of hazardous waste.

- Complying with the regulations for the handling, storage, marking, and disposal of PCBs and PCB items.

- Maximizing the utilization of used POL products, particularly the sale of lubricating oil for re-refining. Use sale proceeds for pollution abatement; energy conservation; occupational safety and health; and morale and welfare projects.

- Implementing source separation/recycling programs at all DOD installations where economically feasible.

- Minimize waste generation through process modification, recycle, reuse, materials substitution or other methods where economically feasible.

- Developing and/or participating with municipalities in resource recovery facilities programs for Standard Metropolitan Statistical Areas (SMSA) where feasible.

1.4 - Installation Restoration Goals

Implement an Installation Restoration (Superfund) program in accordance with Executive Order 12315 and DEQPPM 81-5 by:

- Cooperating with state and EPA Regional officials by providing timely information on IR program status, to include copies of completed Phase I and Phase II reports, and providing other significant monitoring data as requested.

- Identifying sites for Phase II (confirmation studies or surveys) on a continuing basis.

- Programming for Phase IV (remedial action) as requirements are identified. Complete remedial actions.

1.5 - Safe Drinking Water Goals

Provide safe drinking water at DOD activities and comply with the Safe Drinking Water Act (SDWA) by:

- Assuring that all DOD-owned or operated public water supplies are constructed, operated, and maintained in compliance with the SDWA and implementing EPA regulations.

- Performing analyses for chemical, physical, biological, and radiological contaminants as required by EPA or state drinking water standards.

- Assuring that drinking water quality on DOD installations complies with standards established by the SDWA.

- Assuring that water treatment personnel are properly trained.

1.9 - Environmental Auditing Management Goals

- Improve compliance.

- Provide assurance to management that its activities do not contribute to environmental problems which would expose the government to large future financial liabilities or significantly degrade the environment.

- Provide a means of achieving, maintaining and monitoring compliance on a continuous basis.

Appendix C: Environmental and Contract Planning Work Center Description

Natural Resource Planning - prepares, manages, coordinates, implements and maintains the following programs and supporting plans:

Land Management Program/Plan

- Landscape development
- Golf course management
- Urban forestry
- Documents for prime and unique farmland
- Wetlands and flood plains
- Wild and oceanic rivers

Graying and Cropland Management Program Plan (includes applicable outleases)

Forest Management Program/Plan

Endangered species (including biological assessments)

Outdoor Recreation Program/Plan

Natural Resource Planning

- Off road vehicles
- Picnic area management
- Bird watching
- Nature trails
- Photography
- Hiking trails
- National historic trails
- Natural areas

Bird Aircraft Strike Hazard (BASH) Program/Plan

- Nuisance birds

Historic Preservation and Archeology Program/Plan

- Cultural resources management plan

Pest Management Program/Plan

- Nuisance animals, rodents

NOTES: Other natural resource plans are or may be required

Management of preceeding plans includes performing environmental assessments, cooperative agreements, memorandum of understanding (MOUs) as well as preparing, coordinating and gaining approval of reports as applicable.

Additional Areas of Responsibility

Is the single point of contact with local, state and federal agencies for natural resources activities.

Reviews contract drawings and specifications for natural resources impact.

Prepares/coordinates and reviews, in-house and contract environmental impact and assessment process (EIAP) documents.

Prepares submittal for AF and DOD natural resource award programs

Prepares input to public affairs for press release

Advises base executive staff (including tenant units) on all natural resource management programs and plans

Overall manages the development, coordination, implementation and maintenance of plans and programs related to the installation's base comprehensive plan (BCP) to include all component elements indicated in AFR 86-¢(26 Dec 84).

BCP Program Management

In-house planning

Initiatives/Promotes Linkages to related functions:

Planning future EIAP
Planning and real estate/space survey
Planning related studies
Planning and programmers
Host and tenant units

IPF

Plan maintenance

Presentation/briefings

Originates/organizes ·at's and other studies

Contracts

Prepare procurement package "SOW"
AE selection
Manage contract
Implements/integrate

IICEP

Conforms, coordinates with off-base planning organizations

MOUs

Encroachment

AICUZ

Prepares data package
Reviews/revises products from AFESC
Coordinates with MAJCOM, HQ USAF
Release study/public review

Land Use Planning

Prepares and maintains land use plan
Ensure sitings are compatible to land use plan
Prepare area development plans
Manages F-13 agenda/activities
Ensures 1391s are compatible
Provides assistance to functional users
Coordinates input to mission planner
Ensure compatibility with airfield/airspace
Ensure adequate land buffer for development

Transportation Planning

Prepare master transportation plan
Plan traffic engineer studies
Interact with MTMC
Reviews projects for traffic impact

Range Planning

Prepares/maintains range plan
Establish range selection criteria
Coordinates with operational functions

Environmental Planning

Preparation and coordination of the environmental impact analysis process

Prepares for participation in EPC and supporting working groups

Acts as base liaison with federal, state, local and public agencies

Maintains and prepares environmental records and reports which includes:

DRM, DESR, 1383, Spill Reports, Inspection Reports (PCB, Hazardous Waste)

Submittals for incentive awards programs

Management of environmental compliance assessment and management program

Reviews, coordinates O&M, MCP project documents

Provide technical assistance/training to EPC, AF community, other installation organization

Coordinates in long range planning

Monitor implementation of AICUZ and noise program

Operates environmental complaints/suggesting program

Program for future environmental requirements

Maintains currency with all environmental regulation charges

PCB

Develop/implement/monitor PCB inventory control program

Manage/inspect PCB storage facilities

Coordinates PCB disposal

Programming for removal of in service PCB transtorement

Prepare required reports

Hazardous Waste

IRP

Manages Phase I

Evaluates potential for new sites

Maintains/updates data base

Coordinates actions with federal state, local governments

Coordinate Phase II

Review SOW and Phase II draft and final reports
Provides support to Phase II contractor

Manages/implements/maintains Phase IV

Develops SOW for and monitors/oversees RAPS

Makes remedial action alternative selection and defends selections to AFIRM committee

Develops design for remedial action

Monitors remedial action construction

Coordinate action with federal, state and local agencies

Develops and maintains long term monitoring program and O&M requirements needed as result of IRP action

Hazardous Waste Reduction

Identifies/reviews/implements reduction strategies

Hazardous Waste Management

Obtains/maintains R&D permits
Develops & implements & maintains H W Management plan
Identifies/maintains waste stream inventory
Develops/implements training program for H W Handlers
Maintains currency with regulatory changes
Documents and maintains records
Inspects accumulation point and other TSD
Manages H W storage areas

Annually surveys H W disposeal areas
Prepares/manages H W Disposal
Participates in emergency response
Coordinates inspection by outside agencies
Develops and implements correct action

Lust

Inventory existing and decommissioned facilities

Develops/implement/maintain product inventory control testing program

Plan and program for current/future remedial action

Ensure integrity of physical plant maintenance plan

Obtain water usage permits

Implements pretreatment program and measuring and monitoring

Coordinates inspections by outside agencies

Review develops and implements corrective action

Prepare the SPCC plan for different facilities

Develop and prepare surface discharge inventory for NPDES permit

Solid Waste

Monitoring of contract disposal for solid waste

Obtain construction/operating permits for sanitary landfills

Monitoring utilization of landfills

Develop and implement the TWR program

Contract Planning

Determines specific funding source and avenues based upon work required and reviews approval authority documentation to determine proper approval limits and work classification.

Analyzes the projected funding availability to properly develop acceptable project scope.

Justifies work to be done by contract or by in-house work forces.

Establishes a closed audit trail that clearly communicates proper procedure and valid decision making process.

Ensures validity of all projects by field verifying with using organization.

Validates project requirements through the use of technical knowledge, real property records, site visits and user contact.

Coordinates proposed projects with base users, civil engineering shops and headquarters OPRs.

Prepares budget and programming estimates for current and future construction projects.

Prepares all base and tenant project approval documents. Selects the appropriate approval level and office. Ensures timely project approvals.

Ensures active projects under design or construction stay within the approved work classification and funding limit.

Helps prepare and review military construction program (MCP) project booklets and uses and submits systems furniture requirements.

Identifies and validates requirements and develops all planning and programming documents (DD Forms 1391/1391C) in support of facility construction work performed by contract. The different programs include, but are not limited to: O&M, MCP, MFH, P-341, NATO, Infrastructure, NAF, and DODDS. Presents the different programs, for approval on a recurring basis to senior base leadership through the facilities board. Defends the programs to the MAJCOM and Air Staff. Briefs the programs as required to visiting higher headquarters dignitaries, community leaders and congressional staff members.

Prepares, submits and evaluates reports submitted to higher levels of management concerning facility projects by contract for both base facilities and MFH.

Performs socioeconomic and life cycle studies to determine the most cost effective means of providing the facilities required to support the base mission.

Manages base facilities board and acts as recorder. Provides suggested prioritized contract program for board validation. Insures that minutes accurately reflect board actions and takes appropriate programming action.

Represents the base civil engineering organization on other base boards and committees including the quarters improvement committee and the information systems review board and follows up with appropriate programming action.

Acts as engineering branch member of the work request review committee.

Provides consulting services as the base level expert on project funding and accomplishment to base agencies to assist in determining the most economical methods of providing required facility support. Advise the commander on space planning, self help, QIC, beddowns, reorganization, and installation of large equipment items.

Maintains engineering data base for providing management information to base level users and higher headquarters by inputting and updating computer management systems such as CECORS, WIMS, PDC and Z100 systems.

Reviews ISSA's, host tenant agreements, MIPR and other joint agreements for compliance with AF policies and directives and provides advice to the principle parties on BCE related matters.

Backlog of Maintenance and Repair (BMAR)

Develops and maintains a current BMAR program
Submits to Air Staff on an annual basis or as required

Facility Board Minutes

Record minutes of all facility working group and facility board meetings

Insure duplication and distribution of all approved minutes

Maintains the official file of all facility work group and facility board minutes

Prior Year Programs

Serves as the point of contact for all prior year programs

Maintains the official file for all prior year programs

<u>Tracks AF Form 332</u>

Provide status of all 332s on work by contract
Establish audit trail on all 332s

<u>Delegation Letter</u>

Review and maintain all letters of approval authority

Prepare working list for use by the civil engineering function

Serves as the contact point for all project approval levels

<u>Contract Planning</u>: Prepares long-range and short-range planning documents for MCP, MFH, O&M (medical and non-medical) and NAF. Prepares detail documents for short-range contract projects to include: identification of classifications of work; detailed justification for project; cost estimates; planned utilization of existing assets; siting of facility project; functional layouts, etc. Prepares cost studies/economic analysis, and life cycle cost analysis. Prepares individual program priority listings within budget limits. Prepares and maintains contract programming programs in information systems data bases (WIMS, PDC and Z100 systems). Conducts facility assessment studies to realign base activities or functions, or beddown new requirements. Performs socioeconomic studies in support of construction projects. Prepares annual MCP, time sensitive submittals, submittals for inclusion in the program objective memorandum (POM). Prepares and activities/functions on the installation. Prepares agenda for facilities working group and facility minutes.

Appendix D: Comprehensive List of EPF Measures

INPUT CANDIDATES

Candidate	Justification
1. Total military and civilian personnel costs	Identifies primary resource consumed by service oriented EPF
2. Amount of personnel training and education	Shows expertise available to handle technical, complex issues
3. Total manhours (including overtime)	Similar to 1
4. Number of assigned personnel	Indicates at what manning level EPF is operating
5. Cost of supplies and equipment	Identifies resources needed for administrative support
6. Overhead and miscellaneous costs (general administrative and other miscellaneous costs,e.g., TDY)	Similar to 5
7. Contracted services expenditure	Substitutes for personnel costs using services provided by contractors
8. Air pollution sources (number) pollution	Indicates air sources requiring management
9. Water pollution sources (number)	Similar to 8
10. Hazardous waste facilities (number)	Similar to 8
11. Hazardous waste generated (quantity)	Similar to 8

12. Active solid waste landfills (number)	Similar to 8
13. Environmental permits required (number)	Indicates the number of base sources which require permits
14. Past disposal sites with investigative studies completed (number)	Indicates sites which need EPF effort to remediate
15. Natural resources management plans and cooperative agreements (number)	Indicates areas of base which require natural resources management
16. Land available for grazing and cropland management (area)	Identifies the amount of base which has potential for natural resources management
17. Land available for forest management (area)	Same as 16
18. Land available for fish/ wildlife/outdoor recreation (area)	Same as 16

OUTPUT CANDIDATES

Candidate	Justification
1. Total documents reviewed and reports prepared (number)	EPF supports base in ensuring that projects and reports meet regulatory standards
2. Total documents reviewed and reports prepared (manhours)	Same as 1
3. Environmental compliance inspections performed(number)	EPF personnel assist in base inspection of pollution sources and regulated facilities
4. Environmental compliance inspections performed (manhours)	Same as 3
5. Responses to environmental incidents (number)	EPF personnel are key members of base spill response team

6. Responses to environmental incidents (manhours)	Same as 5
7. Environmental training sessions conducted (number)	EPF personnel assist in conducting environmental training
8. Environmental training sessions conducted (manhours)	Same as 7
9. Environmental Impact Analysis Process documents prepared and processed (number)	EPF is responsible for ensuring Air Force projects are assessed for environmental
impact	
10. Environmental Impact Analysis Process documents prepared and processed (manhours)	Same as 9
11. Environmental Protection Committee activity (number)	Committee is oversight body for environmental program; EPF provides primary support
12. Environmental Protection Committee activity (manhours)	Same as 11
13. Effective base population	Evaluates personnel subject to protection
14. Destruction of resources due to pollution incidents (dollar amount)	Indicates how effective EPF is in helping base to avoid incidents
15. Fines and penalties paid (reciprocal dollar amount)	Indicates how effective EPF is in assisting base with achieving compliance
16. Air quality violations (number resolved)	EPF is responsible for preventing or correcting air pollution problems
17. Air pollution sources in compliance (number)	Same as 16
18. Water quality violations (number resolved)	Similar to 16

19. Water pollution sources in compliance (number)	Similar to 17
20. Solid/hazardous waste violations (number resolved)	Similar to 16
21. Solid/hazardous waste facilities in compliance (number)	Similar to 17
22. Environmental permits in compliance (number)	EPF is responsible for ensuring permits are accurate and current
23. Reporting and record keeping discrepancies (number)	EPF ensures that base facilities keep records and prepare reports in accordance with laws
24. Other noncompliance conditions (number)	Indicates non-compliance not accounted for in other similar measures
25. Oil and hazardous substances spills (number)	EPF is responsible for developing spill prevention measures, educating users and ensuring compliance
26. Past disposal sites in site characterization or remediation phases (number)	EPF is responsible for ensuring sites receive required additional work
27. Natural resources management plans/cooperative agreements updated annually (number)	Indicates if EPF has completed plan updates
28. Receipts from grazing and cropland management program (dollar value)	Indicates how well land assets and natural resources are managed
29. Receipts from forest management program (dollar value)	Same as 26
30. Receipts from fish/wildlife/ outdoor recreation program (dollar value)	Same as 26

Appendix E: Data Collection Letter and Survey Form

DEPARTMENT OF THE AIR FORCE
HEADQUARTERS AIR FORCE ENGINEERING AND SERVICES CENTER
TYNDALL AIR FORCE BASE, FL 32403

REPLY TO ATTN OF: DEMG

13 MAY 1986

SUBJECT: Data Collection for Environmental Protection Performance Evaluation

TO: See Distribution List

1. One of the requirements of Project IMAGE is to develop a method to measure productivity for each civil engineering function. The task of initially attempting to measure the Environmental Planning Fucntion (EPF) has been undertaken as a masters degree thesis by an Air Force Institute of Technology (AFIT) student. Your assistance will help in the development of valid measurement techniques for practical use in evaluating Air Force organizations.

2. Mr Steven Coyle, AFIT/LSG, is using an evaluative technique called Constrained Facet Analysis (CFA) which has been successfully demonstrated on other civil engineering functions. EPF performance is difficult to evaluate using tradional techniques because, it is service oriented and has multiple inputs and outputs. Fortunately, CFA has performed well when used to evaluate civil engineering functions with service missions.

3. The data elements concerning EPF operations which will be needed for the CFA model are listed on the attached form. Request that you collect this information for FY85 from the CONUS bases in your command and return to this office by 27 June 1986. Please remind your organizations to carefully read the data request instructions prior to filling out the form. Questions concerning this request should be directed to Mr Coyle by leaving a message at AUTOVON 785-4435/4437.

Paul W. Hains III

PAUL W. HAINS, III, Lt Col, USAF
Chief, Management Division

3 Atch
1. Distribution List
2. Data Request Form
3. Instructions

DISTRIBUTION LIST

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CONSTRAINED FACET ANALYSIS MEASUREMENT DATA
FOR ENVIRONMENTAL PLANNING FUNCTIONS (EPFs)

Demographic Data

Base Name (1)________ MAJCOM Code (2)________

State Code (3)________ EPA Region Code (4)________

EPF Contact Point (5)________ Autovon (6)________

EPF Organization Name and Symbol (7)________

____

Base Size (8)________ Base Population (9)________

Expenditures ($)

Total
Civilian Pay (10)$________

Total
Military Pay (11)$________

Total Cost of
Supplies (12)$________

Total Cost of
Equipment (13)$________

Total Contracted Services Costs (14)$________

Manpower

Total EPF
Manhours (15)________

Natural Resources
only (16)________

Civilian Manhours (17)________ Military Manhours (18)________

Civilian Personnel Assigned (19)________ Authorized (20)________

Military Personnel Assigned (21)________ Authorized (22)________

Responsibilities

Air Pollution Sources (23)________

Water Pollution Sources (24)________

Hazardous Waste Facilities (25)________

Hazardous Waste Generated (26)________

Active Solid Waste Landfills (27)________

Required Environmental Permits (28)________

Natural Resources Plans/Cooperative Agreements (29)________

Activities

	NUMBER	MANHOURS
Total Documents Reviewed	(30)__________	(31)__________
Total Reports Prepared	(32)__________	(33)__________
Environmental Compliance Inspections Performed	(34)__________	(35)__________
Responses to Environ. Incidents	(36)__________	(37)__________
Environ. Prot. Comm. activity	(38)__________	(39)__________
Environ. Documentation Prepared	(40)__________	(41)__________
EAs and EISs only	(42)__________	(43)__________

Compliance

Air Quality Violations:

Previous (44)________ Received (45)________ Resolved (46)________

Air Pollution Source Noncompliance (47)____________

Water Quality Violations:

Previous (48)________ Received (49)________ Resolved (50)________

Water Pollution Source Noncompliance (51)____________

Solid/Hazardous Waste Violations:

Previous (52)________ Received (53)________ Resolved (54)________

Solid/Hazardous Waste Facility Noncompliance (55)______________

Environmental Permits Noncompliance (56)______________

Oil and Hazardous Substances Spills (57)________________

Natural Resources Plans/Agreements Updated (58)______________

Other Noncompliance Conditions (59)________________________________

INSTRUCTIONS

Use the following guidelines to fill out the data request form. All data must be for Fiscal Year 85 (not calender year). Put N/A where data are not applicable or available.

For this study, the Environmental Planning Function (EPF) is defined as that function which deals with environmental planning and resource protection activities. When completing the data elements, do not take into account the activities of base comprehensive planning, Air Installation Compatible Use Zone (AICUZ), or related community planning activities which are commonly accomplished by the EPF. The EPF is usually located in the Civil Engineering Environmental and Contract Planning Section as described in AFR 19-2, paragraph 2.g. Regardless of present EPF location, complete this form using known or estimated data for the EPF as it was operated in FY 85.

NOTE: This information is being collected for statistical purposes only. Your responses will not be identified in the results by either respondent or base (the base name is requested for record keeping purposes only).

1. Self-explanatory.

2. Use:

AAC - 1	AFLC - 2	AFSC - 3	ATC - 4
MAC - 5	SAC - 6	SPACECOM - 7	TAC - 8

3. Use standard two letter code(e.g, Ohio - OH).

4. EPA Region in which base is located (use 1-9).

5-6. Name of EPF contact in case of questions.

7. EPF's organization name or the name of the organization in which the EPF resided in FY 85; include the associated office symbol.

8. Land area (acres) in 1985 from real property records.

9. Effective base population in 1985 from public affairs.

10-11. Estimate using the pay (annual wage/salary divided by 2087 hours) of each EPF person times the number of direct hours spent working on environmental planning and resource protection activities in FY 85.

12-13. In addition to office supplies/equipment, include any response supplies, personnel gear, or pollution control equipment specifically assigned to or designated for EPF use.

14. Estimate only those contractor services, such as special studies and report preparation (usually Title I, Type A contracts), used to supplement EPF staff functions in FY 85. Do not include design or construction contract costs.

15. Total manhours expended in FY 85 for personnel working EPF (environmental and natural resources) activities. Include estimated number of overtime hours even if not compensated.

16. Manhours for natural resources activities only (see item 15).

17. Manhours for the EPF civilian personnel portion of item 15.

18. Manhours for the EPF military personnel portion of item 15.

19, 21. Average number of personnel (including overhires) actually assigned EPF duties during FY 85. Sum the number of months each person was assigned and divide the sum by 12 months.

20, 22. Average number of personnel authorized to work EPF activities during FY 85 according to the Uniform Manning Document (UMD). Sum the number of months each slot was authorized and divide the sum by 12 months.

23. Defense Environmental Status Report (DESR), Table 1, Items 2A and 3A; number of all sources in being.

24. DESR Report, Table 2, Item 2A; number of NPDES permitted discharges in being.

25. DESR Report, Table 4, Item 2; number of all types of hazardous waste facilities.

26. DESR Report, Table 6B, Item 2; total quantity of hazardous waste generated in kilograms.

27. DESR Report, Table 7, Item 2; total number of active solid waste landfills.

28. Number of environmental permits required for base pollution sources (e.g., boilers) or other environmental activities (e.g., landfills).

29. Natural Resources Conservation Report, Item 11; give total number of plans and agreements base had in FY 85.

30-31. Number of documents reviewed in FY 85 for environmental considerations, such as project documentation (e.g., Project Books, 1391s and MCP certification), Material Data Safety Sheets (MSDS), and real estate certification.

32-33. Number of reports, e.g., hazardous waste shipments or air emission testing, required by EPA, state, DOD or other agencies in FY 85.

34-35. List number of inspections made in FY 85 by EPF (separately or as part of team). Include mandatory (required by regulation) and voluntary inspections of pollution control sources and waste facilities.

36-37. Number of EPF personnel responses in FY 85 (separately or team) to spills and other incidents, regardless of severity or whether or not reportable to authorities.

38-39. Number of EPC full committee and working group meetings in FY 85 and number of manhours needed to perform EPC related duties.

40-41. Preparation and/or processing of Environmental Impact Analysis Process (EIAP) documentation in FY 85, including AF Forms 813, 814, and 815, assessments (EA), and impact statements (EIS).

42-43. Of all EIAP documentation, the number of and manhours for EAs and EISs only.

44-46. DESR Report, Table 1, Item 4; number of NOVs previously unresolved (4A), received in FY 85 (4B), and resolved (4C).

47. DESR Report, Table 1, Items 2 and 3; total number out of compliance in FY 85.

48-50. DESR Report, Table 2, Item 3; number of NOVs previously unresolved (3A), received in FY 85 (3B), and resolved (3C).

51. DESR Report, Table 2, Item 2; total number out of compliance in FY 85.

52-54. DESR Report, Table 4, Item 3 and Table 7, Item 3; number of NOVs previously unresolved (3A), received in FY 85 (3B), and resolved (3C).

55. Number of solid/hazardous waste management facility noncompliance conditions not included in data elements 52-54.

56. Number of environmental permits required for base pollution sources or environmental activities which were not in compliance in FY 85 (e.g., out-of-date, permit conditions changed).

57. DESR Report, Table 3, Items 1-4, number of all types of spills occurring in FY 85.

58. Number of plans and agreements which were updated in FY 85.

59. Number of noncompliance conditions in FY 85 (other than those listed above) and law or regulation violated (e.g., asbestos regulations, CERCLA, or FIFRA).

Appendix F: Test Analyses Results

Air Force Civil Engineering Productivity

Efficiency Comparison for Multiple
Efficiency Analyses
Section: DEEV

Test: Results

MAJCOM	BASE	UPPER	LOWER
1	1	1.000	1.000
1	2	1.000	1.000
1	3	1.000	1.000
1	6	1.000	1.000
1	8	1.000	1.000
1	10	0.263	0.170
1	12	1.000	1.000
2	14	0.667	0.667
2	16	1.000	1.000
2	18	0.033	0.033
2	19	1.000	1.000
2	20	1.000	1.000
2	21	0.800	0.800
2	22	1.000	1.000
2	23	1.000	1.000
4	50	1.000	1.000
4	51	1.000	1.000
4	53	1.000	1.000
4	54	1.000	1.000
4	55	1.000	1.000
4	56	1.000	1.000
4	57	0.783	0.783
4	58	1.000	1.000
4	61	1.000	1.000
4	63	0.966	0.966
4	64	1.000	1.000
4	66	1.000	1.000
5	70	1.000	1.000
5	71	1.000	1.000
5	72	1.000	1.000
5	73	0.886	0.886
5	74	1.000	1.000
5	75	1.000	1.000
5	76	1.000	1.000

Air Force Civil Engineering Productivity

Efficiency Comparison for Multiple
Efficiency Analyses
Section: DEEV

Test: Manhours 1

MAJCOM	BASE	UPPER	LOWER
1	1	0.937	0.937
1	2	0.554	0.384
1	3	0.245	0.160
1	6	0.446	0.234
1	8	1.000	1.000
1	10	1.000	1.000
1	12	0.125	0.121
2	14	0.095	0.071
2	16	0.493	0.492
2	18	1.000	1.000
2	19	0.607	0.352
2	20	0.720	0.587
2	21	1.000	1.000
2	22	0.064	0.038
2	23	0.413	0.413
4	50	0.128	0.049
4	51	0.182	0.061
4	53	0.342	0.335
4	54	0.845	0.845
4	55	0.371	0.371
4	56	0.293	0.263
4	57	0.375	0.368
4	58	0.264	0.239
4	61	0.185	0.178
4	63	0.351	0.333
4	64	0.151	0.085
4	66	1.000	1.000
5	70	0.281	0.237
5	71	0.396	0.282
5	72	0.238	0.238
5	73	0.734	0.734
5	74	0.200	0.133
5	75	0.610	0.525
5	76	0.262	0.187

Efficiency Comparison for Multiple
Efficiency Analyses
Section: DEEV

Test: Manhours 2

MAJCOM	BASE	UPPER	LOWER
1	1	1.000	1.000
1	2	0.661	0.654
1	3	0.275	0.247
1	6	0.701	0.701
1	8	1.000	1.000
1	10	1.000	1.000
1	12	0.168	0.168
2	14	0.238	0.090
2	16	0.623	0.623
2	18	1.000	1.000
2	19	0.927	0.927
2	20	0.720	0.587
2	21	1.000	1.000
2	22	0.064	0.059
2	23	0.578	0.474
4	50	0.184	0.184
4	51	0.238	0.204
4	53	0.601	0.440
4	54	0.872	0.800
4	55	0.465	0.465
4	56	0.293	0.264
4	57	0.375	0.350
4	58	0.352	0.334
4	61	0.275	0.275
4	63	0.413	0.356
4	64	0.183	0.165
4	66	1.000	1.000
5	70	0.414	0.414
5	71	0.601	0.601
5	72	0.314	0.304
5	73	0.840	0.840
5	74	0.307	0.307
5	75	1.000	1.000
5	76	0.298	0.298

Efficiency Comparison for Multiple
Efficiency Analyses
Section: DEEV

Test: Costs 1

MAJCOM	BASE	UPPER	LOWER
1	1	0.529	0.314
1	2	0.439	0.428
1	3	0.515	0.508
1	6	0.452	0.169
1	8	1.000	1.000
1	10	1.000	1.000
1	12	1.000	1.000
2	14	0.509	0.279
2	16	0.777	0.295
2	18	0.904	0.904
2	19	0.773	0.350
2	20	0.574	0.574
2	21	1.000	1.000
2	22	0.096	0.049
2	23	0.516	0.195
4	50	0.763	0.763
4	51	0.571	0.183
4	53	1.000	1.000
4	54	1.000	1.000
4	55	0.734	0.480
4	56	0.256	0.256
4	57	0.486	0.486
4	58	1.000	1.000
4	61	0.141	0.126
4	63	1.000	1.000
4	64	0.715	0.507
4	66	1.000	1.000
5	70	0.506	0.506
5	71	1.000	1.000
5	72	0.675	0.617
5	73	1.000	1.000
5	74	0.722	0.722
5	75	1.000	1.000
5	76	0.928	0.928

Efficiency Comparison for Multiple
Efficiency Analyses
Section: DEEV

Test: Costs 2

MAJCOM	BASE	UPPER	LOWER
1	1	1.000	1.000
1	2	0.779	0.776
1	3	1.000	1.000
1	6	0.867	0.666
1	8	0.284	0.282
1	10	1.000	1.000
1	12	0.347	0.347
2	14	0.333	0.330
2	16	0.256	0.242
2	18	1.000	1.000
2	19	0.140	0.128
2	20	0.192	0.177
2	21	1.000	1.000
2	22	0.319	0.314
2	23	0.463	0.460
4	50	1.000	1.000
4	51	0.319	0.319
4	53	1.000	1.000
4	54	0.904	0.592
4	55	1.000	1.000
4	56	0.110	0.110
4	57	0.448	0.448
4	58	1.000	1.000
4	61	0.259	0.155
4	63	0.485	0.457
4	64	0.456	0.023
4	66	1.000	1.000
5	70	0.117	0.113
5	71	1.000	1.000
5	72	0.005	0.005
5	73	1.000	1.000
5	74	0.034	0.032
5	75	0.027	0.027
5	76	0.810	0.773

Efficiency Comparison for Multiple
Efficiency Analyses
Section: DEEV

Test: Costs 3

MAJCOM	BASE	UPPER	LOWER
1	1	0.457	0.457
1	2	0.310	0.310
1	3	0.196	0.196
1	6	0.390	0.390
1	8	0.695	0.615
1	10	1.000	1.000
1	12	0.081	0.081
2	14	0.297	0.290
2	16	0.231	0.231
2	18	0.914	0.914
2	19	0.690	0.690
2	20	0.583	0.583
2	21	1.000	1.000
2	22	0.066	0.066
2	23	0.364	0.364
4	50	0.121	0.121
4	51	0.132	0.132
4	53	0.319	0.319
4	54	0.684	0.684
4	55	0.419	0.419
4	56	0.169	0.169
4	57	0.159	0.159
4	58	0.222	0.222
4	61	0.095	0.095
4	63	0.197	0.197
4	64	0.133	0.133
4	66	1.000	1.000
5	70	0.211	0.211
5	71	0.312	0.312
5	72	0.117	0.117
5	73	0.668	0.668
5	74	0.182	0.182
5	75	0.653	0.653
5	76	0.289	0.289

Efficiency Comparison for Multiple
Efficiency Analyses
Section: DEEV

Test: Costs 4

MAJCOM	BASE	UPPER	LOWER
1	1	0.489	0.489
1	2	0.314	0.314
1	3	0.378	0.378
1	6	0.444	0.444
1	8	0.187	0.187
1	10	0.231	0.231
1	12	0.059	0.059
2	14	0.096	0.096
2	16	0.079	0.079
2	18	1.000	1.000
2	19	0.059	0.059
2	20	0.179	0.179
2	21	0.342	0.342
2	22	0.090	0.090
2	23	0.136	0.136
4	50	0.168	0.168
4	51	0.094	0.094
4	53	0.340	0.340
4	54	0.437	0.437
4	55	0.229	0.229
4	56	0.079	0.079
4	57	0.180	0.180
4	58	1.000	1.000
4	61	0.118	0.118
4	63	0.110	0.110
4	64	0.156	0.156
4	66	0.652	0.652
5	70	0.050	0.050
5	71	0.109	0.109
5	72	0.002	0.002
5	73	0.308	0.308
5	74	0.025	0.025
5	75	0.017	0.017
5	76	0.108	0.108

Efficiency Comparison for Multiple
Efficiency Analyses
Section: DEEV

Test: Air Quality

MAJCOM	BASE	UPPER	LOWER
1	1		
1	2		
1	3		
1	6	1.000	1.000
1	8		
1	10	1.000	1.000
1	12	1.000	1.000
2	14	1.000	1.000
2	16	1.000	1.000
2	18		
2	19	0.933	0.933
2	20	1.000	1.000
2	21	1.000	1.000
2	22	1.000	1.000
2	23	1.000	1.000
4	50	0.250	0.100
4	51		
4	53	1.000	1.000
4	54	1.000	1.000
4	55	0.857	0.857
4	56	1.000	1.000
4	57		
4	58	1.000	1.000
4	61	0.500	0.500
4	63	1.000	1.000
4	64	1.000	1.000
4	66	1.000	1.000
5	70	1.000	1.000
5	71	1.000	1.000
5	72	1.000	1.000
5	73	1.000	1.000
5	74	1.000	1.000
5	75	1.000	1.000
5	76	1.000	1.000

Efficiency Comparison for Multiple
Efficiency Analyses
Section: DEEV

Test: Water Quality

MAJCOM	BASE	UPPER	LOWER
1	1	1.000	1.000
1	2	1.000	1.000
1	3	1.000	1.000
1	6	1.000	1.000
1	8		
1	10	0.100	0.100
1	12		
2	14		
2	16	0.100	0.100
2	18		
2	19	0.449	0.449
2	20	1.000	1.000
2	21	1.000	1.000
2	22	1.000	1.000
2	23	1.000	1.000
4	50		
4	51		
4	53		
4	54	1.000	1.000
4	55	0.500	0.500
4	56	1.000	1.000
4	57		
4	58	0.100	0.100
4	61		
4	63		
4	64		
4	66	1.000	1.000
5	70	1.000	1.000
5	71	0.025	0.025
5	72	0.100	0.100
5	73		
5	74	0.050	0.050
5	75	1.000	1.000
5	76	1.000	1.000

Efficiency Comparison for Multiple
Efficiency Analyses
Section: DEEV

Test: Solid Waste

MAJCOM	BASE	UPPER	LOWER
1	1	0.747	0.747
1	2	0.001	0.001
1	3	1.000	1.000
1	6	1.000	1.000
1	8	1.000	1.000
1	10	0.289	0.289
1	12	0.171	0.171
2	14	0.748	0.748
2	16	1.000	1.000
2	18	1.000	1.000
2	19	0.167	0.167
2	20	1.000	1.000
2	21	0.005	0.005
2	22	1.000	1.000
2	23	0.750	0.750
4	50	1.000	1.000
4	51	1.000	1.000
4	53	0.667	0.667
4	54	0.003	0.003
4	55	1.000	1.000
4	56	1.000	1.000
4	57	1.000	1.000
4	58	1.000	1.000
4	61	1.000	1.000
4	63	0.841	0.841
4	64	0.667	0.667
4	66	1.000	1.000
5	70	0.921	0.921
5	71	1.000	1.000
5	72	1.000	1.000
5	73	1.000	1.000
5	74	0.500	0.500
5	75	1.000	1.000
5	76	0.747	0.747

Efficiency Comparison for Multiple
Efficiency Analyses
Section: DEEV

Test: Violations

MAJCOM	BASE	UPPER	LOWER
1	1		
1	2		
1	3	0.500	0.500
1	6	1.000	1.000
1	8	1.000	1.000
1	10	0.100	0.100
1	12	0.500	0.500
2	14		
2	16	1.000	1.000
2	18		
2	19	0.050	0.050
2	20	1.000	1.000
2	21		
2	22	0.100	0.100
2	23	1.000	1.000
4	50	1.000	1.000
4	51	1.000	1.000
4	53	0.333	0.333
4	54	1.000	1.000
4	55	0.100	0.100
4	56	1.000	1.000
4	57	0.750	0.750
4	58	0.972	0.972
4	61	0.100	0.100
4	63		
4	64		
4	66	1.000	1.000
5	70	0.500	0.500
5	71	0.727	0.727
5	72	0.100	0.100
5	73		
5	74	0.200	0.200
5	75	0.600	0.600
5	76	1.000	1.000

Efficiency Comparison for Multiple
Efficiency Analyses
Section: DEEV

Test: Compliance

MAJCOM	BASE	UPPER	LOWER
1	1	0.624	0.624
1	2	0.504	0.504
1	3	1.000	1.000
1	6	0.143	0.143
1	8	0.252	0.252
1	10	0.051	0.051
1	12	1.000	1.000
2	14	0.323	0.323
2	16	0.092	0.092
2	18	0.018	0.018
2	19	0.024	0.024
2	20	0.240	0.240
2	21	0.199	0.199
2	22	1.000	1.000
2	23	1.000	1.000
4	50	0.756	0.756
4	51	0.500	0.500
4	53	0.390	0.390
4	54	0.036	0.036
4	55	0.116	0.116
4	56	0.087	0.087
4	57	0.072	0.002
4	58	1.000	1.000
4	61	0.156	0.156
4	63	0.486	0.486
4	64	0.848	0.848
4	66	0.310	0.310
5	70	0.013	0.013
5	71	0.296	0.296
5	72	0.168	0.168
5	73	0.886	0.886
5	74	0.201	0.201
5	75	0.890	0.890
5	76	0.118	0.118

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ABSTRACT

The purpose of this research was to determine if an analysis method could be developed for the Civil Engineering Environmental Planning Function. The modeling technique chosen for this effort was Constrained Facet Analysis (CFA) which is capable of evaluating an organization based on a set of multiple inputs and outputs. The most time-consuming aspect of the research was determining appropriate input and output measures for environmental planning organizations, since the functions are service-oriented and have few variables which are suitable for typical quantitative analysis. Many of the variables selected were considered "result" oriented in that they measured the effectiveness of functions in meeting compliance requirements. The model evaluated the measures to identify efficiency ratings for environmental planning organizations and identified which variables caused the inefficiencies. The analysis was accomplished by collecting data from base environmental functions and processing the data using the computerized CFA model, Productivity Assessment Support System. The results showed that, with certain limitations, the measures and CFA could be used to model the performance of environmental organizations. Field study of CFA use for Air Force Civil Engineering was recommended.

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